PERFORMANCE BASED EARTHQUAKE DESIGN

A Thesis
Submitted by

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UNDER THE SUPERVISION OF

PROF. PRADIP SARKAR

In partial fulfillment of the requirements
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IN
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National Institute of Technology
Rourkela

CERTIFICATE

This is to certify that this report entitled, "**Performance Based Earthquake Design**" submitted by **Ankush Bansal (108CE033)** in partial fulfillment for the award of Bachelor of Technology Degree in Civil Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision.

To the best of my knowledge, the matter embodied in this report has not been submitted to any other university/institute for the award of any degree or diploma.

Date: 9th May 2012

Prof. Pradip Sarkar
Department of Civil Engineering
(Project Guide)

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In spite of numerous citations above, the author accepts full responsibility for the content that follows.

Ankush Bansal

ABSTRACT

***Key words**: Performance based design approach, nonlinear static analysis, point plastic hinge model, Pushover Analysis*.

Every Civil Engineering structure or building is unique in nature unlike other engineering products which are produced in a massive scale using the same technique again and again. The present Project is an effort to understand Performance Based Design Approach. In this Work an four storey office building is designed using STAAD.Pro and a nonlinear static analysis is carried out using point plastic hinge model. After the building is designed it is imported to SAP platform in order to model point plastic hinges and carry out Pushover Analysis. The designed building was modeled and the hinges or possible failure locations were assigned. The stiffness of the building was increased due to the slab present and this was incorporated in the model using diaphragm. The Floor Centre of Mass was calculated and an incremental Inverted triangular loading was applied to this central load and the base shear along with displacement of this building was recorded until the building reached a state of collapse. The Displacement controlled Pushover Analysis was carried out and the Pushover Curve were obtained for the building in both the direction i.e. X and Y. The Pushover curve is analyzed for various percentage of displacement. As per FEMA 356 typical values of roof drifts for the three performance levels are as follows.

i) Immediate Occupancy: Transient drift is about 1% with negligible permanent drift.

ii) Life Safety: Transient drift is about 2% with 1% permanent drift.

iii) Collapse Prevention: 4% inelastic drift, transient or permanent.

The Capacity Spectrum, Demand Spectrum and Performance point of the building was found in both the direction using the analysis carried out in SAP 2000 (v14). From the Performance point it was found that the Base Shear carried by the building is well above the design base shear and the building can take a lateral force up to 10% of the seismic weight of the building. The Displacement obtain was less than 1% and hence the chances of crossing the elastic state for the building was very less. Very Rare chances are there for the building to cross Life safety performance level. In the collapse state the failure was due to the collapse of ground floor Columns which is a serious issue and should be looked for further research. The Building designed as per Indian standards was found to be well above Life safety performance level considering Designed Based Earthquake .

NOTATIONS & ABBREVIATION

E	Young's Modulus
ρ	Density
α	Temperature Coefficient
M20	Grade of Concrete
f'_{cc}	Yield Stress
ε_{cc}	Yield Strain
ε_{cu}	Maximum Strain
f_y	Yield stress of steel
ε_y	Yield strain of steel
Z	Zone factor
I	Importance factor
RF	Response reduction factor
M3	Flexural moment
P-M2-M3	Axial force with biaxial moment
T_a	Fundamental natural period of vibration
V_B	Design Base Shear
W	Seismic weight of building
A_h	Design horizontal acceleration spectrum
S_a/g	Spectral acceleration coefficient
Q_i	Lateral force in ith Floor
W_i	Seismic weight of ith Floor
h_i	Height of ith Floor

PBSD :	Performance Based Seismic Design
PBSE :	Performance Based Seismic Engineering
RC :	Reinforced Concrete
IS :	Indian Standards
DL :	Dead Load
LL :	Live Load
COM :	Centre of mass
ADRS :	Acceleration displacement response spectrum

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1. INTRODUCTION

1.1 PERFORMANCE BASED DESIGN

The promise of performance-based seismic engineering (PBSE) is to produce structures with predictable seismic performance. This approach is not new using this approach/model Turbines, Airplanes & Automobiles are made. In these applications one or more prototype are built and subjected to extensive testing. To incorporate the lessons learned from the experimental evaluations the design and manufacturing process is then revised, Once the cycle of design, prototype manufacturing, testing and redesign is successfully completed, the product is manufactured in a massive scale. In the automotive industry, for example, millions of automobiles which are virtually identical in their mechanical characteristics are produced following each performance-based design exercise. Performance Based Earthquake Engineering/Design is not that popular because the scale of output is not large in comparison to the Automobile industry and others. Each building designed by this process is virtually unique and the experience obtained is not directly transferable to buildings of other types, sizes, and performance objectives. Therefore, up to now PBSE has not been an economically feasible alternative to conventional prescriptive code design practices. In coming few years we can say that Performance Based Design will become the standard method of delivering Earth Quake resistant designs.

The facts are clear – We cannot prevent big, destructive earthquakes from occurring. These pose a continuing threat to lives and property in more than 55% of the area of this country. However, it is possible to avoid the disastrous consequences of an earthquake and that precisely is the objective of every seismic design code practice. The seismic codes are framed primarily with the objective of prevention of loss of life. In order to meet this objective it is essential that the structures/constructed facilities respond to the expected earthquake ground motions at the site in a designated manner, which in turn depends on the nature of ground motion exciting the structure.

Thus the reliability of achieving the life safety performance objective of any constructed facility is governed by the most uncertain element in the chain- expected ground motion.

Seismic hazard and Damage state are the two essential parts of a Performance Objective. Seismic performance is described by designating the maximum allowable damage state (performance level) for an identified seismic hazard (earthquake ground motion). The target Performance level is split into two levels Non-structural damage and Structural damage, the combination of the two gives the building a combined performance level. The various Performance levels are described in detail in the next section 1.2 .

In increasing order of structural displacement the various Performance levels shown here are Operational , Immediate Occupancy , Life Safety and Last one is Collapse Prevention.

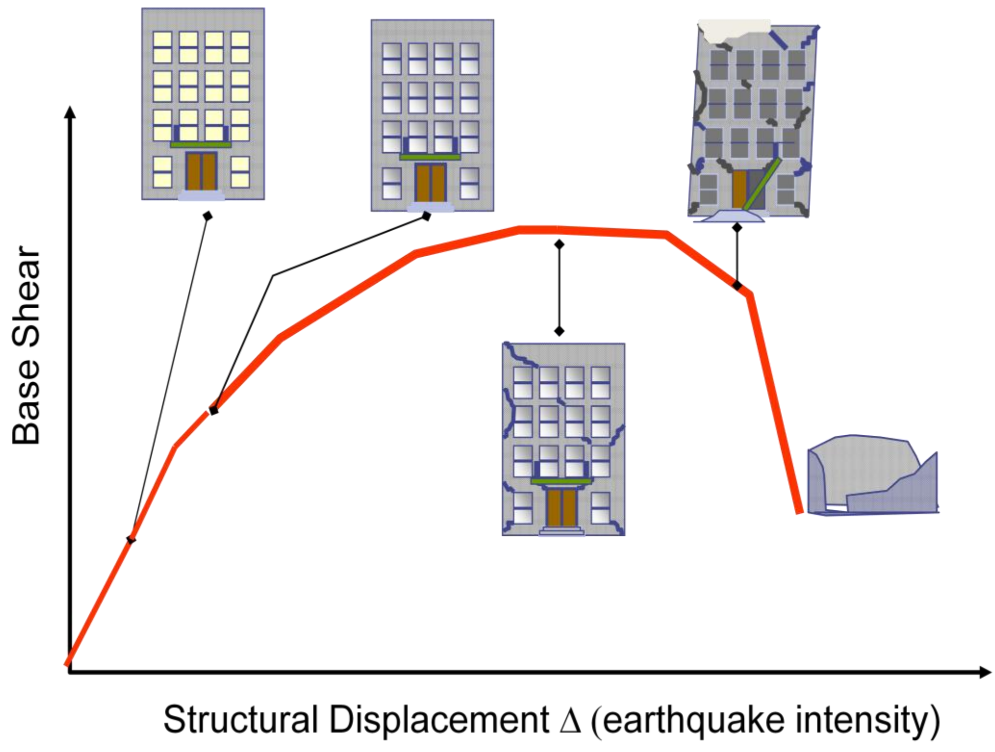


Figure 1:Building Performance Levels

1.2 BUILDING PERFORMANCE LEVELS

The Various Performance levels are tabulated below with their affects on both Structural and Non-structural elements.

TABLE 1: Performance Levels

Performance Level	Structural Performance	Non Structural Performance
Operational (O)	Very light damage No permanent drift Substantially original strength and stiffness	Negligible damage. Power & other utilities are available
Immediate Occupancy (IO)	Light damage No permanent drift Substantially original strength & stiffness Minor cracking Elevators can be restarted Fire protection operable	Equipments & content secure but may not operate due to mechanical/utility failure
Life Safety (LS)	Moderate damage Some permanent drift Residual strength & stiffness in all stories Gravity elements function Building may be beyond economical repair	Falling hazard mitigated but extensive systems damage
Collapse Prevention (CP)	Severe damage Large permanent drifts Little residual strength & stiffness Gravity elements function Some exits blocked Building near collapse	Extensive damage

1.3 BUILDING DETAILS

The building is a four storeyed office building located in Rourkela (Zone II). It is a bit unsymmetrical building (refer to the figure below). The building has uniform storey height of four meter.

The dimensions of beams & columns are 400mm x 400mm for all the sections. The thickness of both the internal and external walls are taken same and equal to 250mm. The density of brick is assumed to be 20Kn/m^2.

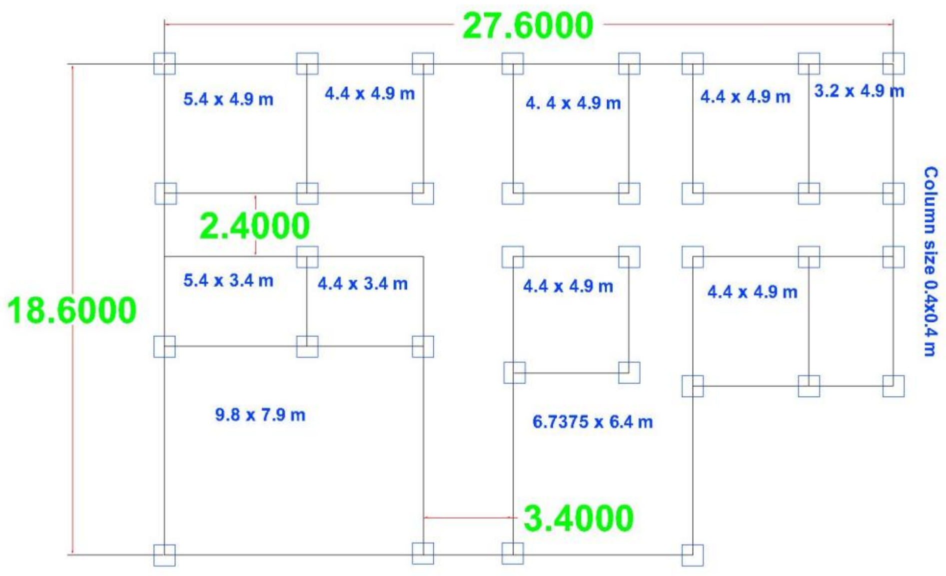


Figure 2:Top View/ Plan of the proposed office building

The building consists of 400 beams and columns in total. The various materials and their properties used for the designing of this building are given in section 2.2 .

1.4 OBJECTIVE & SCOPE

The objective of the present study is identified as to design and evaluate a RC framed building using performance based design approach. Followings are the scope of the present study:

a) Only RC framed building is considered.
b) Liner, Non-linear Static & Linear Dynamic analysis is carried out using point plastic hinge model. Non-linear Dynamic analysis is kept outside the scope of the work.
c) Fixity is considered to model the column end at support. Other support condition/soil structure interaction is ignored.
d) Infill wall is not modeled for stiffness but the loading is modeled as per IS 456: 2000

1.5 METHODOLOGIES

a) Carry out literature review to understand the PBSD philosophy.
b) Develop a floor plan in AUTOCAD
c) Model the building in STADD-PRO for analysis and design.
d) Develop Non-linear hinge properties for each frame section.
e) Model the building in SAP 2000 for PB analysis.
f) Analysis of the building using linear Static, Dynamic & Non-linear Static analysis approach.
g) Analysis of the result.

<u>THE PROCESS</u>

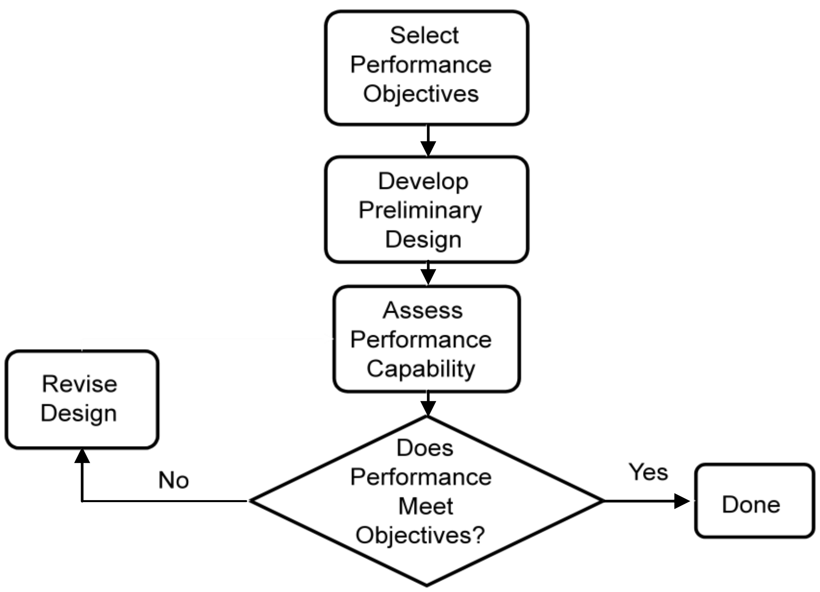


Figure 3: An algorithm showing the whole process

1.6 ORAGNISATION OF THESIS

The 1st Chapter 'INTRODUCTION' has presented a brief background about performance objective and it's need in present scenario, objective & scope of the project work carried out , the various performance levels and the details of the building which is to be designed and analyzed. Lastly methodology along with problem details & expected solutions are discussed.

Chapter 2 starts with a Introduction and the need for Structural modeling. It contains the description of material properties & later on explains the details of modeling carried out in STAAD.Pro & SAP 2000. Lastly the obtained reinforcement is shown and summarized in a tabulated form.

In the 3rd Chapter a introduction is provided about performance based evaluation. A detailed description about Pushover Analysis procedure and Nonlinear Plastic Hinge Properties are given. Later the results obtained from Pushover Analysis are discussed and presented. In the end a brief summary about the whole evaluation is given.

The fourth chapter summarizes and concludes the whole Project work.

Chapter five contains the list of various References used during the project and are referred from time to time for valuable cooperation.

Chapter six and seven contains two Appendix A & B respectively. A contains the Input STAAD file and B contains the calculation showing Floor Mass Center.

2. STRUCTURAL MODELING

2.1 INTRODUCTION

The whole chapter describes about the properties of the materials used for designing, the modeling procedure followed, Calculation of Base Shear as per IS code, the obtained RCC design and finally summarizes the whole Structural Modeling.

The Building is first modeled in STAAD.Pro and subjected to Dead Load, Live Load & Earthquake Load under various Load Combinations. The STAAD output file gave the reinforcement required for sustaining the loads under the worst possible condition. Base Shear is calculated using the provisions given in IS 1893:2002 and the obtained pattern is plotted for reference. The reinforcements derived from STAAD output file are grouped and saved in the form of reinforcement results. With the obtained results the file is imported to SAP 2000, where the obtained reinforcement is provided and the building is subjected to loads and Pushover Analysis is carried out.

During Modeling in SAP 2000 for pushover analysis precautions were taken in defining the hinge properties and their locations. The stiffness provided by the slab is taken into account through diaphragm action.

2.2 MATERIAL PROPERTIES

The Materials used for the designing of the Office Building was M20 grade concrete and reinforcing steel Fe 415. The concrete possessed the following properties:

a. Young's Modulus (E) = 2.05 e + 008 kN/m^3
b. Poisson Ration = 0.3
c. Density = 25 kN/m^3
d. Alpha = 1 e-005
e. Damping ratio = 0.05

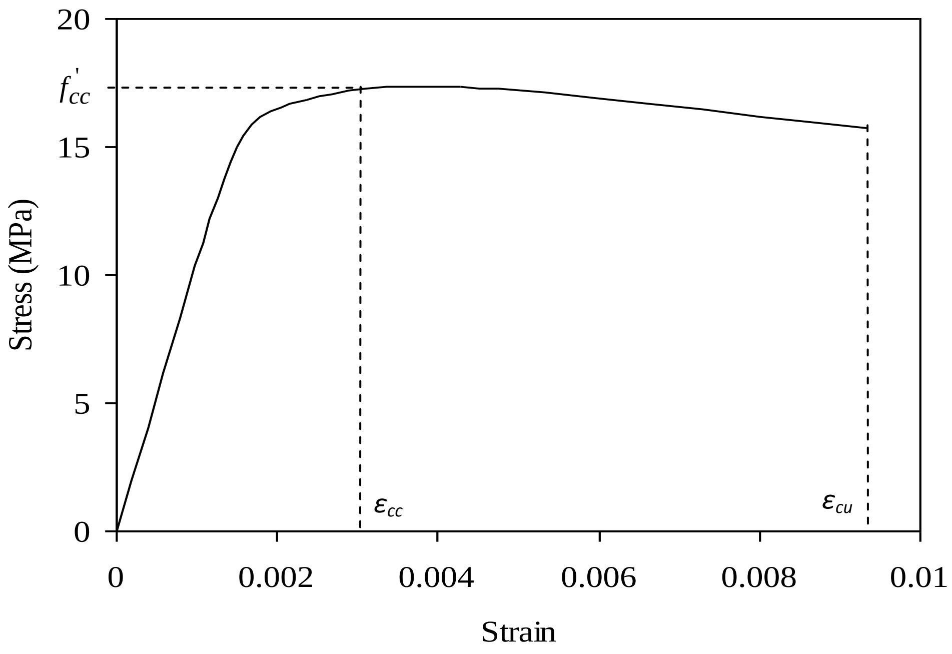


Figure 4: Typical stress-strain curve for M-20 grade concrete (Panagiotakos and Fardis, 2001)

The reinforcing steel possessed the following properties

a. Young's Modulus (E) = 2.17185 e +007 kN/m^3
b. Poisson ration = 0.17
c. Density = 76.8195 kN/m^3
d. Alpha = 1.2 e-005

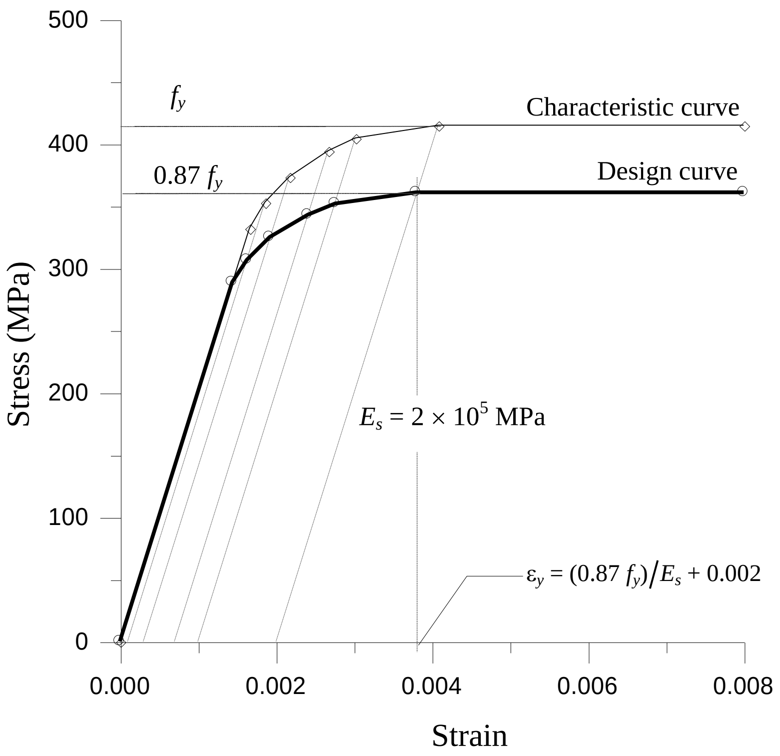


Figure 5: Stress-strain relationship for reinforcement – IS 456 (2000)

The dimension of all the beams & columns were taken as 400mm × 400mm.

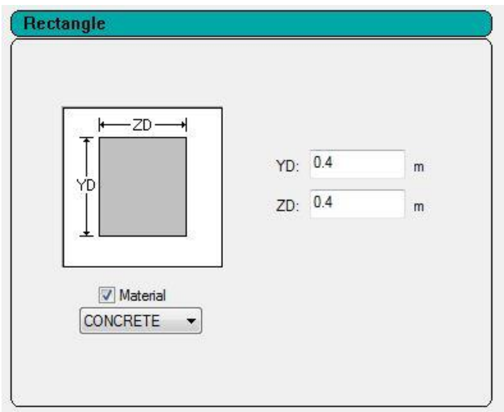


Figure 6: A screen shot showing sectional dimension

2.3 MODELING

The Building is designed to resist Dead load, Live load & Seismic load. Various load combinations were tried as per IS 456 and the worst case was taken into account to design the respective member.

Dead load Consists of Self weight, Brick load & Floor load. Self weight was calculated automatically using the assigned density & dimension. Brick load was taken as 20 kN/m over the beams.

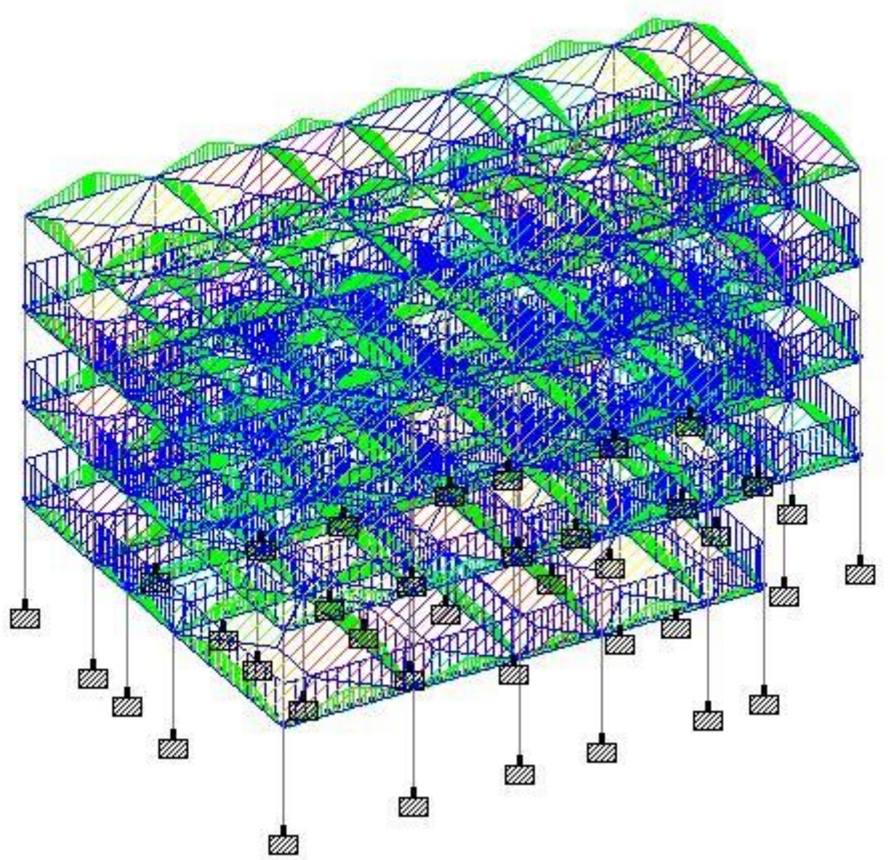


Figure 7: Showing Brick load acting on Beams

Floor load was taken as 3.75 kN /m^2 taking the slab thickness as 150 mm.

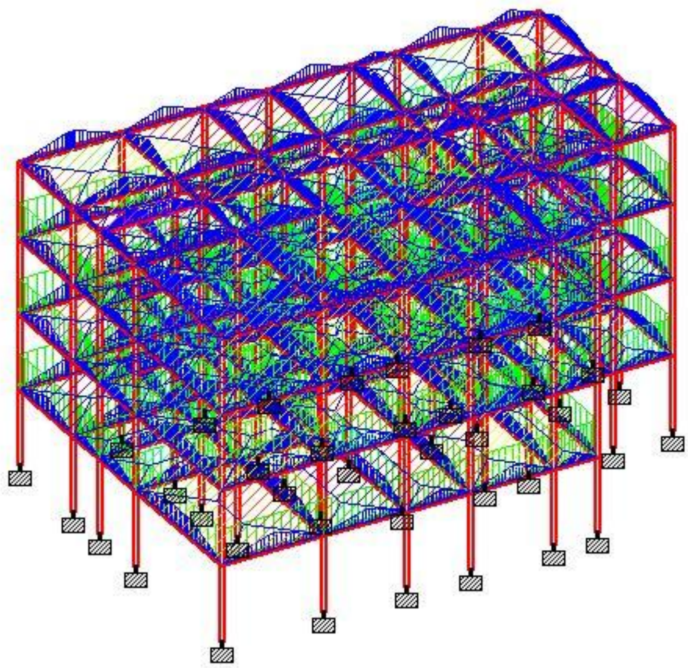


Figure 8: Showing Floor Load acting on Slabs

As per IS code instructions the Live load was taken to be 3 kN/m^2.

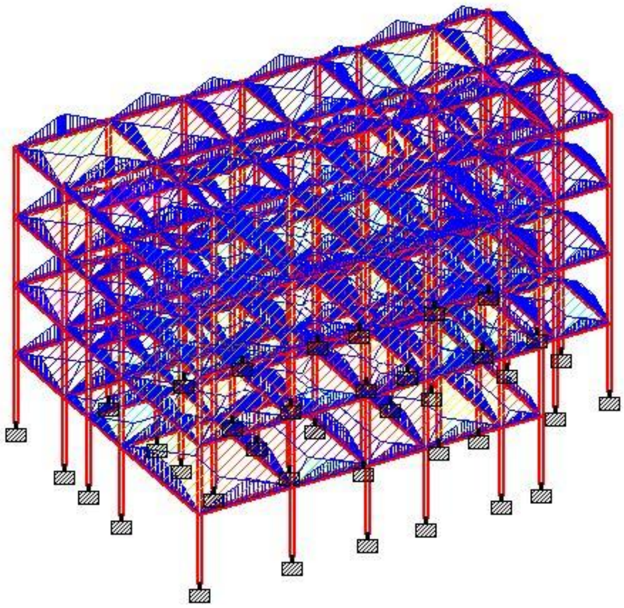


Figure 9: Showing Live Load acting on Slabs

As per IS 1893:2002 the following seismic parameters were used to calculate the seismic forces & design.

Zone Factor (Rourkela) = 0.10 (Zone II)
Importance Factor = 1.0 (Office Building)
Response reduction factor (RF) = 3 (Ordinary Moment Resisting Frame)
Damping ratio = 0.05

A 3D view of the office building:-

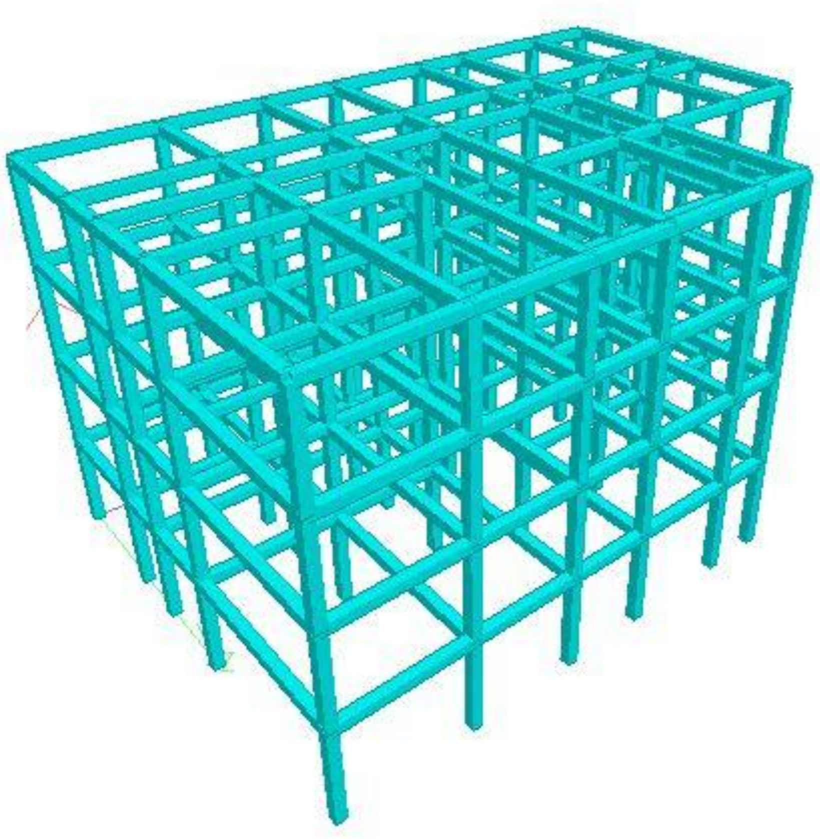


Figure 10 : A 3D View of the Designed Building

Modeling of Structural Elements

Beams and columns are modeled by 2D frame elements. The beam-column joints are modeled by giving end-offsets to the frame elements, to obtain the bending moments and forces at the beam and column faces. The beam-column joints are assumed to be rigid (Fig. 11). The column end at foundation was considered as fixed for all the models in this study. All the frame elements are modeled with nonlinear properties at the possible yield locations.

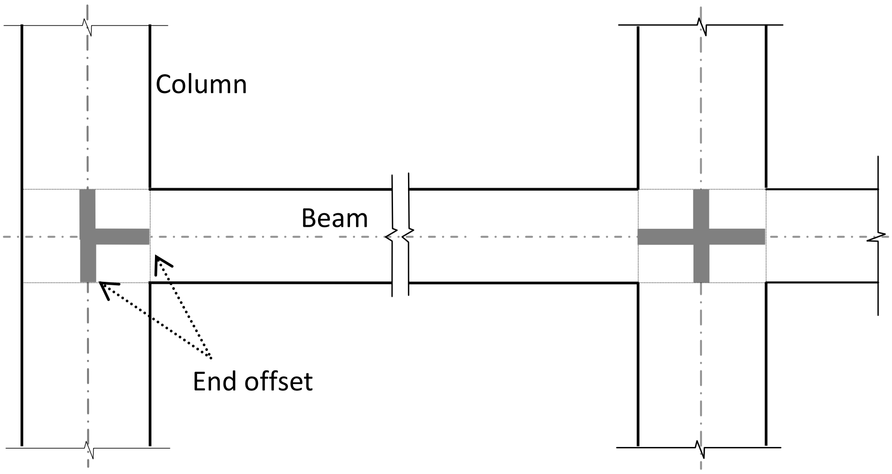


Figure 11: Use of end offsets at beam-column joint

The structural effect of slabs due to their in-plane stiffness is taken into account by assigning 'diaphragm' action at each floor level. The mass/weight contribution of slab is modeled separately on the supporting beams.

Modeling of Flexural Plastic Hinges

In the implementation of pushover analysis, the model must account for the nonlinear behavior of the structural elements. In the present study, a point-plasticity approach is considered for modeling nonlinearity, wherein the plastic hinge is assumed to be concentrated at a specific point in the frame member under consideration. Beam and column elements in this study were modeled with flexure (M3 for beams and P-M2-M3 for columns) hinges at possible plastic regions under lateral load (*i.e.*, both ends of the beams and columns). Properties of flexure hinges must simulate the actual response of reinforced concrete components subjected to lateral load. In the present study the plastic hinge properties are calculated by SAP 2000 (v14).

Top view & Front View of the building :-

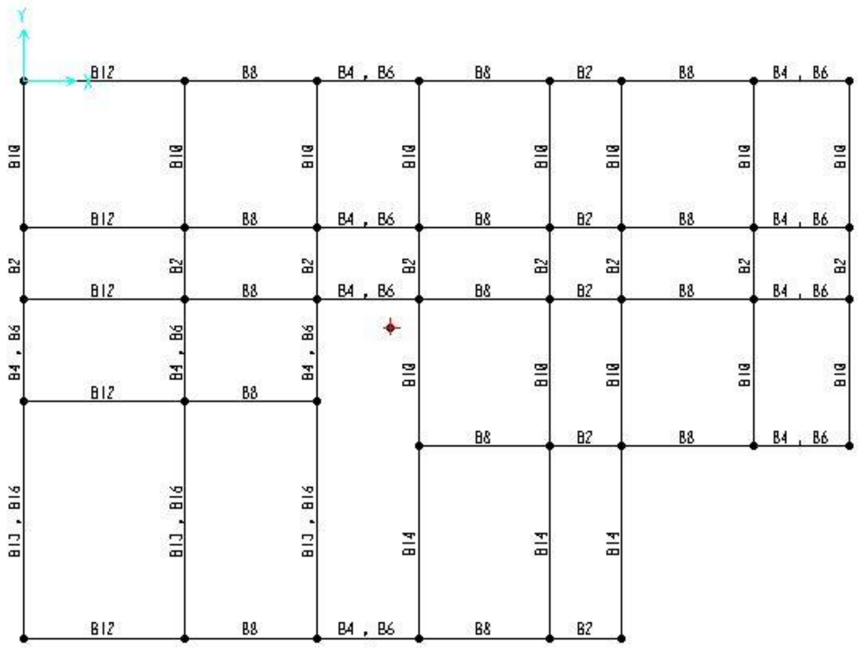


Figure 12 : Top View of the Building with Reinforcement Grouping

After the assignment of the property to the structural elements the COM(centre of mass) of the building was found and node was created at the point in all the storey's.

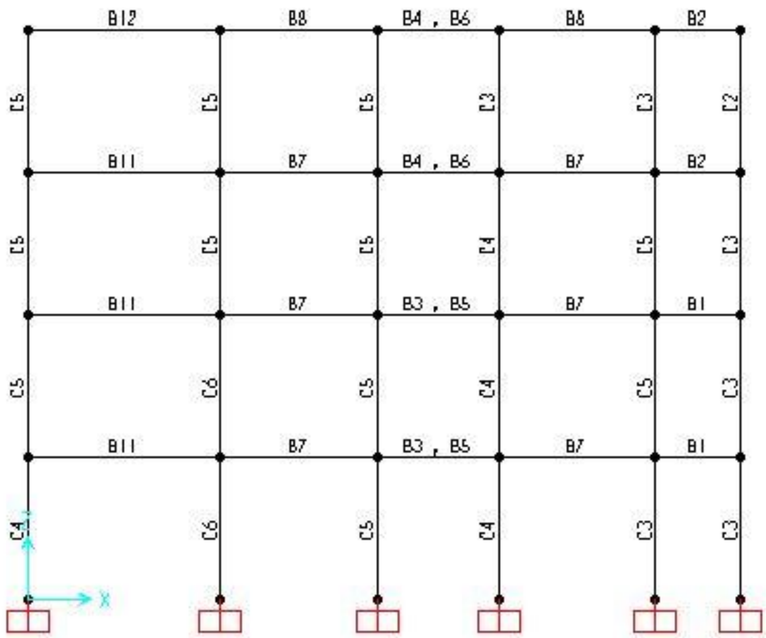


Figure 13 : Front View of the Building with Reinforcement Grouping

2.4 CALCULATION OF BASE SHEAR

Using IS 1893:2002 Base Shears for the designed building was calculated.

Percentage (%) of imposed load in Seismic Weight calculation was taken as 25 % .

- **Seismic Weight calculation**

  Top Floor:-

  20×263 + 2×38×0.4×0.4×25 + 263×0.4×0.4×25 + 464.72×3.75 + 0

  = 8358.7 kN

  1st, 2nd & 3rd Floor :-

  5260 + 2×304 + 1052 + 1742.7 + 0.25×3×464.72

  = 9011.24 kN

Seismic Weight of the Building = 8358.7 + 9011.24×3 = 35392.42 kN

$\mathbf{T_a = 0.09h/\sqrt{d}}$, where

'd'= Base dimension of the building at the plinth level, in m, along the considered direction of the lateral force.

'h'= Height of building in m

In X direction: T_a= 0.2741 s

In Y direction: T_a=0.3339 s

Spectral acceleration (s_a/g) is 2.5 for both of the two fundamental periods (i.e., in X- and Y-directions)

Design base shear = $\mathbf{V_B = A_h w}$

$$A_h = \left(\frac{Z}{2}\right)\times\left(\frac{I}{R}\right)\times\left(\frac{S_a}{g}\right) = \left(\frac{0.10}{2}\right)\times\left(\frac{1}{3}\right)\times(2.5) = 0.042$$

Design base shear = .042 × 35392.42 = 1486.464 kN

Vertical distribution of Base shear gave the following results

1st floor = 51.47 kN

2nd floor= 205.88 kN

3rd floor= 463.25 kN

4th floor = 763.92 kN

2.5 RCC DESIGN

- **BEAMS**

TABLE 2: Reinforcement Details of Beams from STAAD output File

BEAM NO.	LENGTH IN mm	TOP R (O) in mm^2	TOP R(MID) in mm^2	TOP R(END) in mm^2	BOTOM R (o) in mm^2	BOTTOM R (m) in mm^2	BOTTOM R (e) in mm^2	BEAM NAME
43	2400	1108	302	1146	634	302	617	B1
47	2400	1460	302	1040	694	302	856	B1
54	2400	1207	302	1232	651	302	642	B1
64	2400	1245	302	1253	660	0	662	B1
67	2400	1108	302	1096	540	302	546	B1
71	2400	1311	302	1401	802	302	1051	B1
92	2400	1277	302	1319	691	302	708	B1
93	2400	1492	302	1096	675	302	841	B1
94	2400	1473	302	1063	656	302	816	B1
95	2400	1425	302	1307	650	302	729	B1
96	2400	1348	302	1247	611	0	681	B1
97	2400	1324	302	1233	592	302	650	B1
98	2400	1226	302	1199	547	300	562	B1
143	2400	982	302	1010	553	302	539	B1
147	2400	1291	302	1066	682	302	739	B1
154	2400	1075	302	1089	576	300	569	B1
164	2400	1104	302	1102	589	300	590	B1
167	2400	1003	302	995	505	302	509	B1
171	2400	1053	302	1318	730	302	855	B1
192	2400	1111	302	1195	643	302	620	B1
193	2400	1334	302	1149	683	302	722	B1
194	2400	1301	302	1105	662	302	705	B1
195	2400	1283	302	1216	618	302	655	B1
196	2400	1213	302	1166	585	0	622	B1
197	2400	1176	300	1142	562	300	592	B1
198	2400	1101	302	1080	512	0	523	B1
243	2400	646	302	650	302	302	302	B2
247	2400	808	302	688	322	300	362	B2
254	2400	705	302	701	302	302	302	B2
264	2400	724	302	706	302	302	302	B2
267	2400	679	302	678	302	302	302	B2
271	2400	598	300	789	345	300	384	B2
292	2400	720	302	788	302	302	302	B2
293	2400	824	302	751	323	302	332	B2
294	2400	815	302	725	316	302	331	B2

295	2400	823	302	782	302	302	302	B2
296	2400	797	302	756	302	0	302	B2
297	2400	774	302	739	302	302	302	B2
298	2400	745	302	731	302	0	302	B2
343	2400	302	302	302	302	302	302	B2
347	2400	302	302	302	302	302	302	B2
354	2400	302	302	302	302	302	302	B2
364	2400	302	302	302	302	302	302	B2
367	2400	302	302	302	302	302	302	B2
371	2400	302	302	302	302	302	302	B2
392	2400	302	302	302	302	302	302	B2
393	2400	302	302	302	302	302	302	B2
394	2400	302	302	302	302	302	302	B2
395	2400	302	302	302	302	302	302	B2
396	2400	302	302	302	302	302	302	B2
397	2400	302	302	302	302	302	302	B2
398	2400	302	302	302	302	302	302	B2
45	3200	1216	302	1246	543	302	725	B3
56	3200	1345	302	1334	544	302	759	B3
66	3200	1347	302	1340	559	302	775	B3
73	3200	1329	302	1349	830	302	595	B3
145	3200	1027	300	1177	498	300	589	B3
156	3200	1134	302	1289	511	299	622	B3
166	3200	1153	302	1309	520	302	630	B3
173	3200	1262	302	1171	695	302	543	B3
245	3200	676	302	779	302	302	302	B4
256	3200	738	302	851	302	302	302	B4
266	3200	750	302	859	302	302	302	B4
273	3200	798	302	774	329	302	302	B4
345	3200	302	302	302	302	302	302	B4
356	3200	302	302	308	302	302	302	B4
366	3200	302	302	309	302	302	302	B4
373	3200	302	302	302	302	302	302	B4
41	3400	1121	302	1181	453	302	429	B5
48	3400	1027	302	1805	641	302	442	B5
52	3400	1234	302	1307	460	302	433	B5
62	3400	1378	302	1334	481	302	503	B5
69	3400	1372	302	1431	597	300	569	B5
82	3400	1081	302	1934	631	302	560	B5
83	3400	1041	302	1977	655	302	599	B5
141	3400	1054	302	1081	404	302	385	B5
148	3400	1161	302	1576	545	302	433	B5
152	3400	1181	302	1196	427	302	395	B5
162	3400	1353	302	1203	450	302	471	B5

169	3400	1264	302	1333	536	302	505	B5
182	3400	1248	302	1722	524	302	379	B5
183	3400	1172	302	1806	568	300	444	B5
241	3400	775	302	786	302	302	302	B6
248	3400	838	302	1279	305	302	302	B6
252	3400	857	302	859	302	302	302	B6
262	3400	998	302	846	302	302	302	B6
269	3400	923	0	985	302	302	302	B6
282	3400	924	302	1387	308	302	302	B6
283	3400	866	302	1506	302	302	302	B6
341	3400	302	302	302	302	302	302	B6
348	3400	382	302	408	302	302	302	B6
352	3400	302	302	302	302	302	302	B6
362	3400	394	0	302	302	302	302	B6
369	3400	302	302	320	302	302	302	B6
382	3400	412	302	633	302	302	0	B6
383	3400	371	302	717	302	302	302	B6
40	4400	1436	302	1198	376	325	300	B7
42	4400	1215	302	1179	353	387	302	B7
44	4400	1148	302	1214	339	391	302	B7
51	4400	1552	302	1336	392	401	302	B7
53	4400	1368	302	1306	371	480	302	B7
55	4400	1282	302	1352	355	480	302	B7
61	4400	1556	302	1351	400	393	302	B7
63	4400	1380	0	1321	380	482	302	B7
65	4400	1311	302	1364	362	487	302	B7
68	4400	1524	0	1291	421	348	325	B7
70	4400	1357	0	1253	398	404	302	B7
74	4400	1443	302	1291	302	469	376	B7
84	4400	1725	302	1509	463	481	480	B7
88	4400	1510	0	1471	503	567	302	B7
140	4400	1344	302	1200	355	330	300	B7
142	4400	1187	302	1183	341	379	302	B7
144	4400	1165	302	1182	334	388	302	B7
151	4400	1480	302	1347	373	408	302	B7
153	4400	1359	0	1336	361	471	302	B7
155	4400	1328	302	1334	354	476	302	B7
161	4400	1485	302	1367	382	394	302	B7
163	4400	1356	0	1335	370	474	302	B7
165	4400	1357	302	1342	361	479	302	B7
168	4400	1466	0	1295	404	351	302	B7
170	4400	1358	0	1246	392	397	302	B7
174	4400	1433	302	1272	302	446	375	B7
184	4400	1594	302	1511	436	476	388	B7

188	4400	1499	0	1428	469	552	300	B7
240	4400	1058	302	932	302	328	302	B7
242	4400	969	300	968	300	384	300	B7
244	4400	968	300	966	300	396	300	B7
251	4400	1211	302	1046	302	408	302	B7
253	4400	1071	0	1060	302	474	302	B7
255	4400	1067	302	1052	302	481	302	B7
261	4400	1212	302	1054	300	397	300	B7
263	4400	1074	0	1067	302	478	302	B7
265	4400	1091	302	1056	302	485	302	B7
268	4400	1172	300	986	300	351	300	B7
270	4400	1068	0	972	302	400	302	B7
274	4400	1180	302	1018	302	457	302	B7
284	4400	1305	302	1146	302	479	302	B7
288	4400	1165	0	1103	302	554	302	B7
340	4400	311	302	307	302	302	302	B8
342	4400	302	302	329	302	302	302	B8
344	4400	342	302	302	302	302	302	B8
351	4400	453	302	404	302	302	302	B8
353	4400	401	302	426	302	302	302	B8
355	4400	438	302	372	302	302	302	B8
361	4400	441	302	403	302	302	0	B8
363	4400	387	302	426	302	302	302	B8
365	4400	447	0	369	302	302	302	B8
368	4400	362	302	327	302	302	302	B8
370	4400	376	302	318	302	302	302	B8
374	4400	384	0	353	302	302	302	B8
384	4400	484	302	425	302	302	0	B8
388	4400	432	0	420	300	343	300	B8
46	4900	1645	0	1522	523	549	302	B9
57	4900	1429	302	1382	416	517	300	B9
72	4900	1388	302	1422	342	516	300	B9
76	4900	1777	0	1655	525	742	302	B9
77	4900	1735	0	1632	512	712	302	B9
78	4900	1702	0	1615	496	713	302	B9
79	4900	1642	302	1561	473	674	302	B9
80	4900	1590	302	1532	460	673	302	B9
81	4900	1590	302	1536	432	708	302	B9
87	4900	1934	302	1496	579	595	373	B9
89	4900	1798	302	1435	435	534	354	B9
90	4900	1439	302	1740	348	579	376	B9
91	4900	1533	302	1567	354	701	302	B9
146	4900	1647	0	1465	491	540	299	B9
157	4900	1427	302	1333	384	494	302	B9

172	4900	1340	302	1421	327	491	302	B9
176	4900	1790	0	1601	492	723	302	B9
177	4900	1747	0	1577	480	693	302	B9
178	4900	1717	0	1575	466	689	302	B9
179	4900	1651	302	1529	444	650	302	B9
180	4900	1624	302	1520	432	648	302	B9
181	4900	1578	302	1491	404	683	302	B9
187	4900	1819	300	1531	433	593	371	B9
189	4900	1717	302	1499	352	541	353	B9
190	4900	1490	302	1675	346	583	306	B9
191	4900	1524	302	1581	343	677	302	B9
246	4900	1316	0	1159	305	543	302	B9
257	4900	1086	302	1061	302	505	302	B10
272	4900	1062	302	1084	302	500	302	B10
276	4900	1480	0	1332	307	731	0	B9
277	4900	1454	0	1315	302	701	0	B9
278	4900	1432	0	1321	302	697	0	B9
279	4900	1351	302	1258	302	658	302	B9
280	4900	1337	302	1264	302	656	302	B9
281	4900	1327	302	1266	302	692	302	B9
287	4900	1635	302	1317	265	593	300	B9
289	4900	1501	302	1263	302	543	302	B9
290	4900	1245	300	1474	300	584	300	B9
291	4900	1282	302	1319	302	687	302	B9
346	4900	437	0	335	302	302	302	B10
357	4900	350	302	324	302	302	302	B10
372	4900	319	302	350	302	302	302	B10
376	4900	593	0	496	302	458	302	B10
377	4900	552	0	482	302	427	302	B10
378	4900	539	302	506	302	420	302	B10
379	4900	495	302	475	300	382	300	B10
380	4900	486	302	474	300	381	300	B10
381	4900	509	302	500	302	408	302	B10
387	4900	775	302	547	0	314	302	B10
389	4900	611	0	524	302	302	302	B10
390	4900	532	302	526	300	350	300	B10
391	4900	502	302	504	302	400	302	B10
39	5400	1583	302	1693	415	674	324	B11
50	5400	1703	302	1821	435	824	435	B11
58	5400	1693	0	1768	466	709	405	B11
59	5400	1829	0	1922	468	926	567	B11
60	5400	1707	0	1826	444	764	464	B11
139	5400	1558	302	1590	372	653	302	B11
150	5400	1731	302	1766	393	800	403	B11

158	5400	1698	0	1678	424	682	308	B11
159	5400	1828	0	1814	442	888	427	B11
160	5400	1717	0	1749	404	743	386	B11
239	5400	1295	302	1375	302	660	302	B11
250	5400	1470	302	1522	302	808	302	B11
258	5400	1437	0	1430	302	686	44	B11
259	5400	1584	0	1592	299	905	216	B11
260	5400	1448	0	1503	302	751	110	B11
339	5400	427	302	414	302	329	302	B12
350	5400	577	302	629	302	471	302	B12
358	5400	520	0	448	300	387	0	B12
359	5400	698	0	711	300	575	0	B12
360	5400	517	0	579	302	412	0	B12
75	6400	1978	302	1786	599	810	391	B13
86	6400	2128	300	2422	763	1384	1073	B13
100	6400	2263	300	2054	909	1232	687	B13
175	6400	1930	302	1855	574	793	498	B13
186	6400	2145	300	2351	780	1349	999	B13
200	6400	2167	300	2063	789	1191	682	B13
275	6400	1719	302	1613	355	803	302	B13
286	6400	1900	300	2218	520	1359	854	B13
300	6400	1997	300	1833	619	1206	451	B13
375	6400	488	302	458	302	302	302	B14
386	6400	895	302	1316	300	796	300	B14
400	6400	1014	302	843	302	657	0	B14
49	7900	2791	368	2611	1465	1732	1274	B15
85	7900	3403	736	2997	2118	2082	1685	B15
99	7900	3474	917	3125	2140	2267	1778	B15
149	7900	2741	322	2644	1414	1691	1308	B15
185	7900	3344	623	3066	2046	2000	1750	B15
199	7900	3520	800	3348	2225	2178	2049	B15
249	7900	2645	336	2478	1309	1705	1136	B15
285	7900	3319	632	3062	2017	2009	1746	B15
299	7900	3497	807	3351	2202	2185	2053	B15
349	7900	1264	302	1085	302	876	0	B16
385	7900	1927	302	1661	571	1349	291	B16
399	7900	2116	302	1904	772	1564	549	B16

- **COLUMNS**

TABLE 3 : Reinforcement Details of Columns from STAAD output File

COLUMN NO.	AREA OF STEEL REQUIRED	TIE REINFORCEMENT	REINFORCEMENT TYPE
	IN mm^2	dia, specing (mm)	
333	430	8,300C/C	C1
335	872	8,300C/C	C1
327	874	8,300C/C	C1
324	917	8,300C/C	C1
135	997	8,300C/C	C1
233	1011	8,300C/C	C1
332	1278	8,300C/C	C2
19	1280	8,300C/C	C2
119	1280	8,300C/C	C2
218	1280	8,300C/C	C2
312	1280	8,300C/C	C2
313	1280	8,300C/C	C2
314	1280	8,300C/C	C2
315	1280	8,300C/C	C2
316	1280	8,300C/C	C2
317	1280	8,300C/C	C2
318	1280	8,300C/C	C2
319	1280	8,300C/C	C2
320	1280	8,300C/C	C2
323	1280	8,300C/C	C2
325	1280	8,300C/C	C2
326	1280	8,300C/C	C2
334	1280	8,300C/C	C2
336	1280	8,300C/C	C2
20	1346	8,300C/C	C2
35	1360	8,255C/C	C2
212	1399	8,255C/C	C2
27	1417	8,255C/C	C2
226	1436	8,255C/C	C2
235	1441	8,255C/C	C2
219	1460	8,255C/C	C2
227	1464	8,255C/C	C2
220	1465	8,255C/C	C2
223	1472	8,255C/C	C2
120	1495	8,255C/C	C2
236	1514	8,255C/C	C2
214	1520	8,255C/C	C2
103	1523	8,255C/C	C2

216	1524	8,255C/C	C2
127	1541	8,255C/C	C2
225	1543	8,255C/C	C2
17	1573	8,255C/C	C3
224	1574	8,255C/C	C3
133	1576	8,255C/C	C3
15	1599	8,255C/C	C3
13	1671	8,255C/C	C3
32	1676	8,255C/C	C3
230	1690	8,255C/C	C3
34	1709	8,255C/C	C3
203	1721	8,255C/C	C3
126	1747	8,255C/C	C3
118	1754	8,255C/C	C3
125	1811	8,300C/C	C3
117	1816	8,300C/C	C3
116	1847	8,300C/C	C3
132	1858	8,300C/C	C3
124	1865	8,300C/C	C3
134	1893	8,300C/C	C3
114	1910	8,300C/C	C3
217	1912	8,300C/C	C3
115	1917	8,300C/C	C3
215	1926	8,300C/C	C3
24	1943	8,300C/C	C3
25	1946	8,300C/C	C3
234	1981	8,300C/C	C3
16	1989	8,300C/C	C3
14	1991	8,300C/C	C3
337	1994	8,300C/C	C3
213	2013	8,300C/C	C3
232	2058	8,300C/C	C3
112	2073	8,300C/C	C3
113	2076	8,300C/C	C3
37	2088	8,300C/C	C3
331	2099	8,300C/C	C3
18	2138	8,300C/C	C3
26	2153	8,300C/C	C3
23	2214	8,300C/C	C4
130	2386	8,255C/C	C4
12	2415	8,300C/C	C4
136	2446	8,300C/C	C4
31	2572	8,300C/C	C4
8	2759	8,300C/C	C4

33	2816	8,300C/C	C4
231	2902	8,300C/C	C4
131	2911	8,300C/C	C4
30	3072	8,300C/C	C5
237	3126	8,300C/C	C5
36	3200	8,255C/C	C5
137	3336	8,255C/C	C5
338	3801	8,300C/C	C5

2.6 SUMMARY

The Reinforcement obtained above in section 2.5 is grouped and presented below in a tabular form.

TABLE 4 : Grouped Reinforcements of Beams

BEAM NAME	TOP REINFORCEMENT(mm^2)	BOTTOM REINFORCEMENT(mm^2)	BAR SIZE, NO.OF BARS (T, B)
B1	1570	1256	20,5 & 20,4
B2	1005	804	16,5 & 16,4
B3, B5	1570	942	20,5 & 20,3
B4,B6	804	402	16,4 & 16,2
B7	1963	603	25,4 & 16,3
B8	628	402	20,2 & 16,2
B9	1963	942	25,4 & 20,3
B10	1206	603	16,6 & 16,3
B11	1963	1005	25,4 & 16,5
B12	942	603	20,3 & 16,3
B13,B16	2454	1963	25,5 & 25,4
B14	1256	804	20,4 & 16,4
B15	4021	2454	32,5 & 25,5

TABLE 5 : Grouped Reinforcements of Columns

COLUMN NAME	AREA OF STEEL REQUIRED (mm^2)	STEEL PROVIDED (BAR SIZE, NO.S)
C1	1011	20,4
C2	1553	16,8
C3	2177	16,12
C4	2911	20,10
C5	4578	16,24
C6	5768	25,12

3. PERFORMANCE BASED EVALUATION

3.1 INTRODUCTION

Force Based design is a traditional approach to Seismic Design of a Building. Using the Response Spectrum the design lateral forces on the Building are determined & the members are designed to withstand these forces. In this approach, there is no measure of the deformation capability of a member or of the building. At best, an elastic drift is computed under the design forces and checked against an elastic drift limit. Alternatively, an inelastic drift is estimated from the calculated elastic drift by multiplying the later by a factor and checking the inelastic drift against an inelastic drift limit.

In performance based analysis the deformations of the members and the building as a whole are quantified under the lateral forces of an earthquake of a certain level of seismic hazard. The deformations or strains are better quantities to assess damage than stresses or forces. A performance based analysis requires a nonlinear lateral load versus deformation curve as the deformations are expected to go beyond the elastic curve. The performance based analysis gives the analyst more choices of 'performance' of the building as compared to the limit states of collapse and serviceability in a design based on limit state method.

3.2 PUSHOVER ANALYSIS PROCEDURE

Pushover analysis involves the application of increasing lateral forces or displacements to a nonlinear mathematical model of a building. The nonlinear load-deformation behaviour of each component of the building is modelled individually. In a force-controlled push, the forces are increased monotonically until either the total force reaches a target value or the building has a collapse mechanism. In a displacement-controlled push, the displacements are increased monotonically until either the displacement of a predefined control node in the building exceeds a target value or the building has a collapse mechanism. For convenience, the control node can be taken at the design centre of mass of the roof of the building. The target displacement is intended to represent the maximum displacement likely to be experienced during the earthquake.

Initially, the gravity loads are applied in a force-controlled manner till the total load reaches the target value. The target value can be same as the design gravity load for the linear analysis. Next, the lateral loads are applied in the X- or Y- direction, in a displacement controlled manner. The direction of monitoring of the behaviour is same as the push direction. The effect of torsion can

be considered. As the displacement is increased, some beams, columns and 'equivalent struts' may undergo in-elastic deformation. The non-linear in-elastic behaviour in flexure, shear or axial compression is modelled through assigning appropriate load-deformation properties at potential plastic hinge locations.

LATERAL LOAD DISTRIBUTION

The design Base shear distribution which was shown in section 2.5 was evaluated using the expression , $\mathbf{Q_i = w_i h_i^2 / \sum w_i h_i^2}$ according to IS 1893:2002 .

For push over analysis an inverted triangular loading is taken which is shown below.

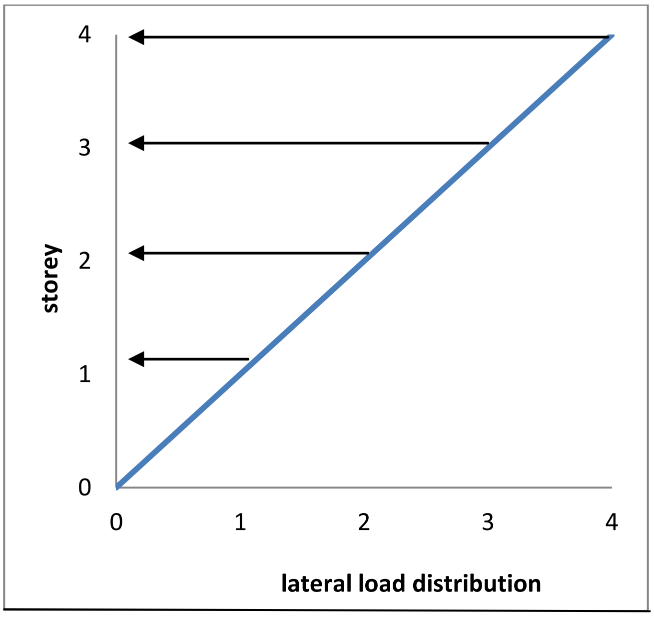
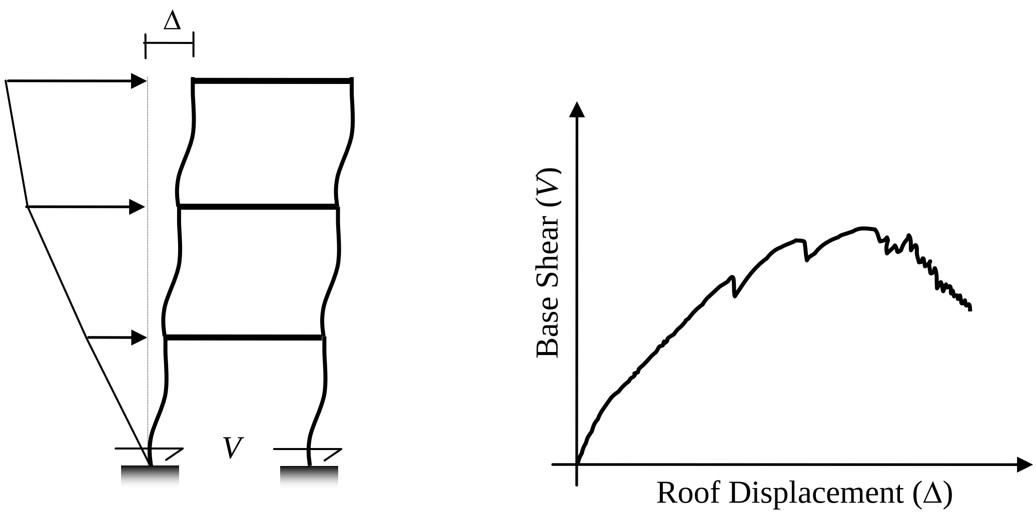


Figure 14 : Lateral load used for Pushover Analysis

The same load pattern is applied to the central node for Push Over Analysis in both X and Y direction.

PUSHOVER ANALYSIS

Pushover Analysis is a nonlinear, static procedure in the lateral loads magnitude is incrementaly increased , maintaining a predefined distribution pattern along the height of the building. Weak links and failure modes of the buildings are found with the help of the increase in the magnitude of the loads.



a) Building model

b) Pushover curve

Figure 15: Pushover Analysis Procedure

Pushover analysis can determine the behavior of a building, including the ultimate load and the maximum inelastic deflection. Local nonlinear effects are modeled and the structure is pushed until a collapse mechanism is developed (Figure 15). At each step, the base shear and the roof displacement can be plotted to generate the pushover curve. It gives an idea of the maximum base shear that the structure is capable of resisting. For regular buildings, it can also give a rough idea about the global stiffness of the building.

3.3 NONLINEAR PLASTIC HINGE PROPERTIES

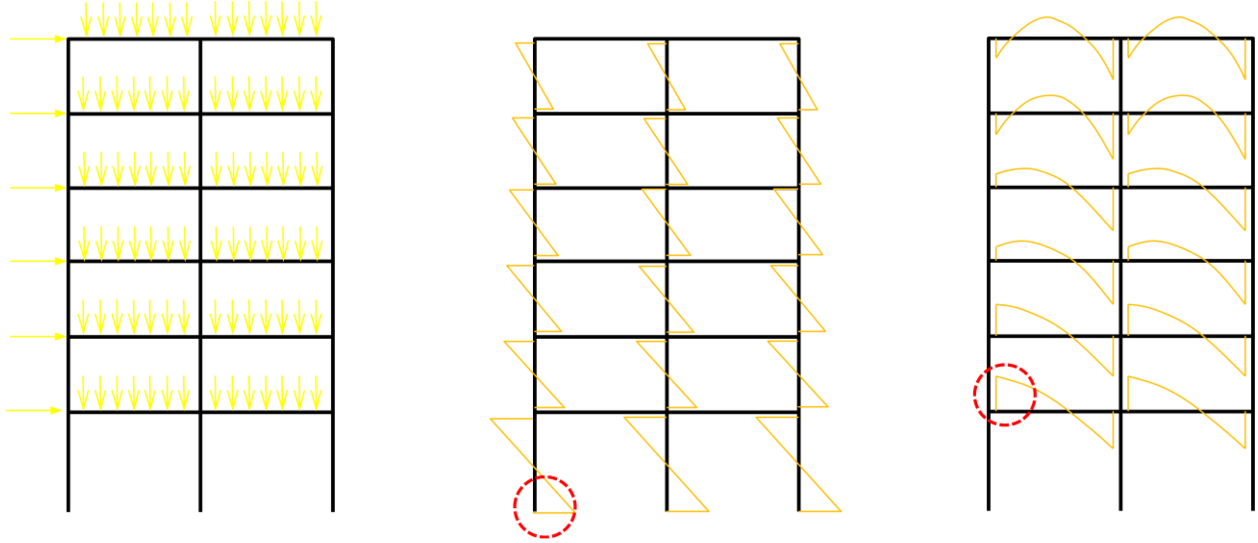


Figure 16: Modeling RC Framed Building

The above (Figure 16) is showing the possible failure points due to Shear and Bending Moment. It is necessary to model the nonlinear load deformation of the elements in Pushover Analysis. Beams and columns should have moment versus rotation and shear force versus shear deformation hinges.

There are two ways of specifying Hinge properties Distributed plasticity model and Point plasticity model. We have used point plasticity model where zone of yielding is assumed to be concentrated at a specific point in the element. . In the present study the plastic hinge properties are calculated by SAP 2000.

Point	Moment/SF	Rotation/SF
E-	-0.2	-0.025
D-	-0.2	-0.015
C-	-1.1	-0.015
B-	-1	0
A	0	0
B	1.	0.
C	1.1	0.015
D	0.2	0.015
E	0.2	0.025

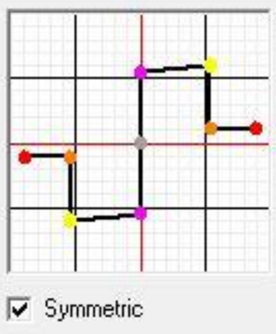


Figure 17: Typical Hinge Properties by SAP 2000 (V14)

Flexural hinges in this study are defined by moment-rotation curves calculated based on the cross-section and reinforcement details at the possible hinge locations. For calculating hinge properties it is required to carry out moment–curvature analysis of each element. Constitutive relations for concrete and reinforcing steel, plastic hinge length in structural element are required for this purpose. The flexural hinges in beams are modelled with uncoupled moment (M3) hinges whereas for column elements the flexural hinges are modelled with coupled P-M2-M3 properties that include the interaction of axial force and bi-axial bending moments at the hinge location. Although the axial force interaction is considered for column flexural hinges the rotation values were considered only for axial force associated with gravity load.

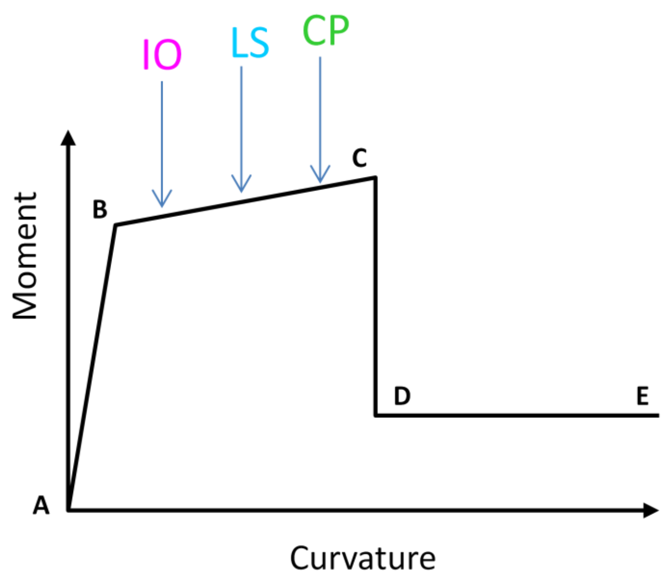


Figure 18: A typical Moment-Curvature relation

This Digram Shows a Moment Curvature relation where it can be seen that till point B the relation is linear and after point B the Curvature have increased significantly with minor increase in Moment resistance. The Yielding from B to C is continous but we have done Discrete divison into three Levels namely Immediate Occupancy (IO), Life Safety (LS), Collapse Prevention (CP).

In indian Standards we design building so that the structural members are subjected to Life Safety limit in Designed Based Earthquake (DBE) and Collpase Prevention Limit in Maximum Considered Earthquake.

In our present study this Moment-Curvature relation is automatically generated by SAP using FEMA guidelines and the provided section dimension and reinforcement.

3.4 RESULTS

Pushover Analysis was conducted over the designed building using SAP 2000(V14) with the inverted triangular loading pattern as shown in figure 14. The members were assigned with their self weight and the analysis was carried out for (DL + 0.25LL) incremantally under control. The building is pushed in lateral directions untill the collapse mechanism is reached. The various curves resulting from the analysis are briefed in the following text.

Pushover Curve- along X direction-

Figure 18 shows the Pushover Curve along X direction for the building.

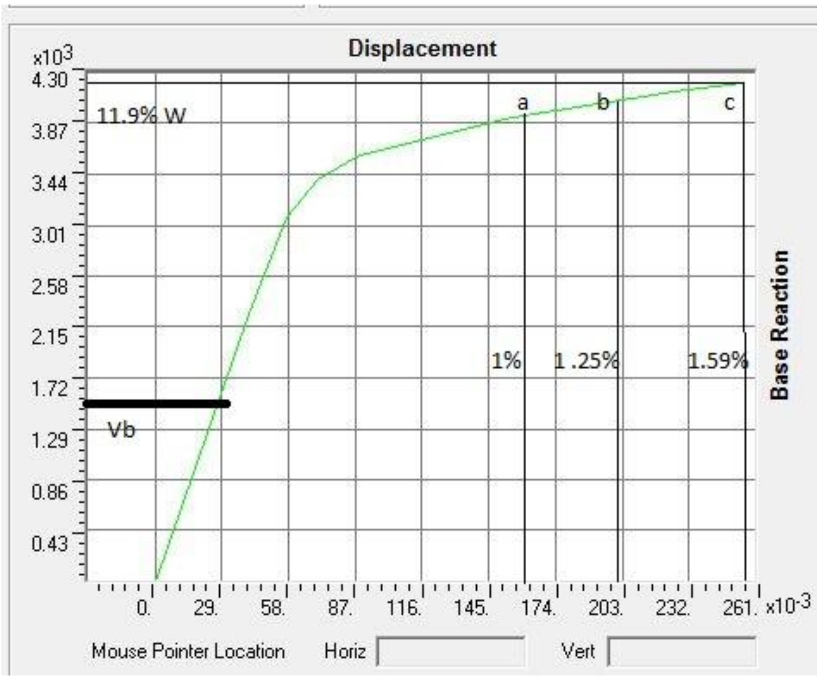


Figure 19: Pushover Curve along X direction

The unit for Base Reaction is kN and Displacement is metre. The maximum node displacement is equal to 0.255 m which is 1.59% H. The Pushover Curve shows that the building has fairly high Base Shear Capacity than the Design Base Shear. Points ‘a’ , ‘b’ , ‘c’ are marked on the curve corresponding to 1% , 1.25% and 1.59% of Displacement respectively. The Base Shear Capacity of the building is approximately 11.9% of the seismic weight of the Building.

Figure 20 shows the formation of hinges in a typical frame of building at point ‘a’ (1%) displacement.

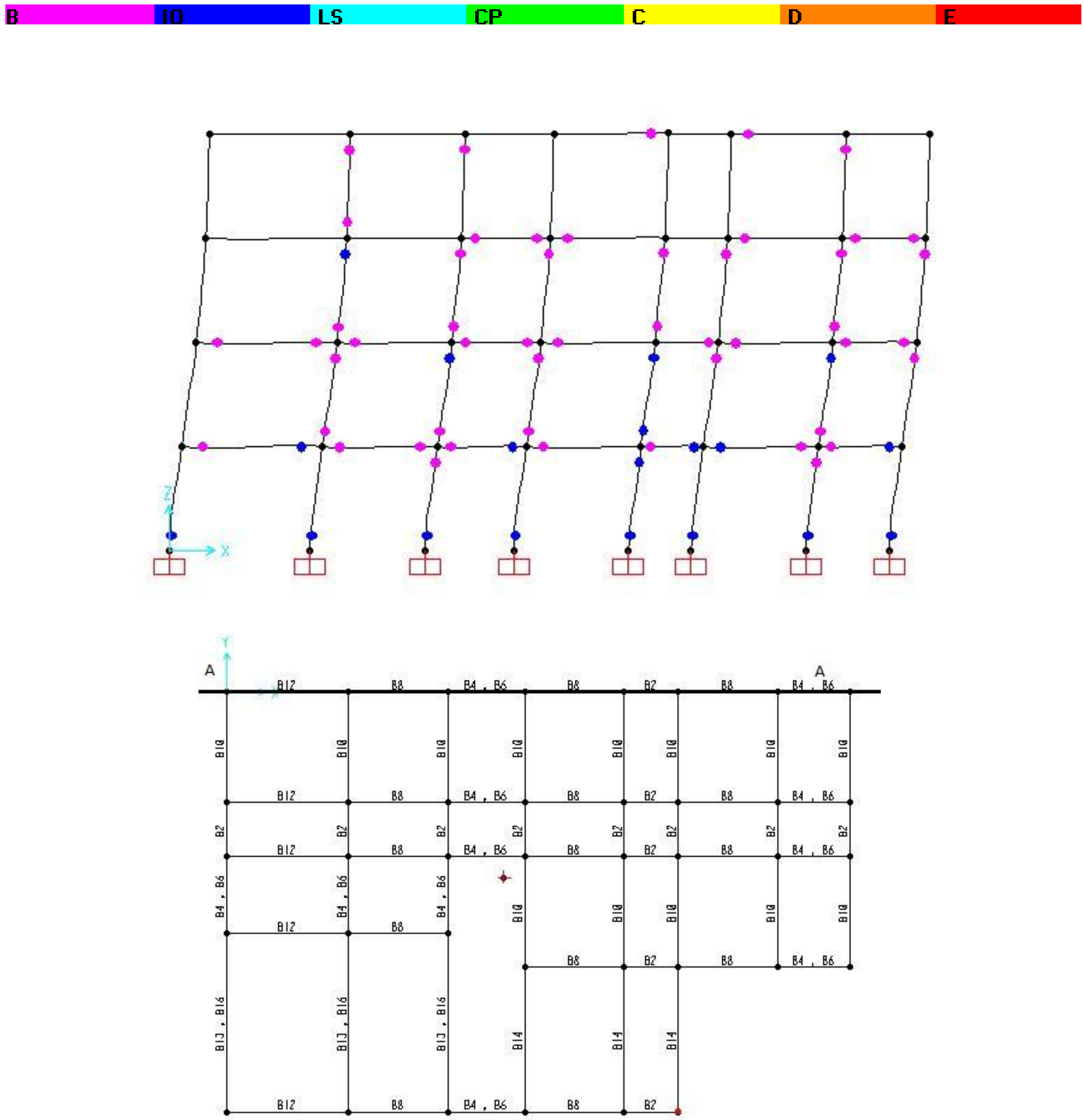


Figure 20: Formation of Hinges in typical frame at point ‘a’ and along section A-A

Figure 21 shows the formation of hinges at point ‘b’ (1.25%) along section A-A

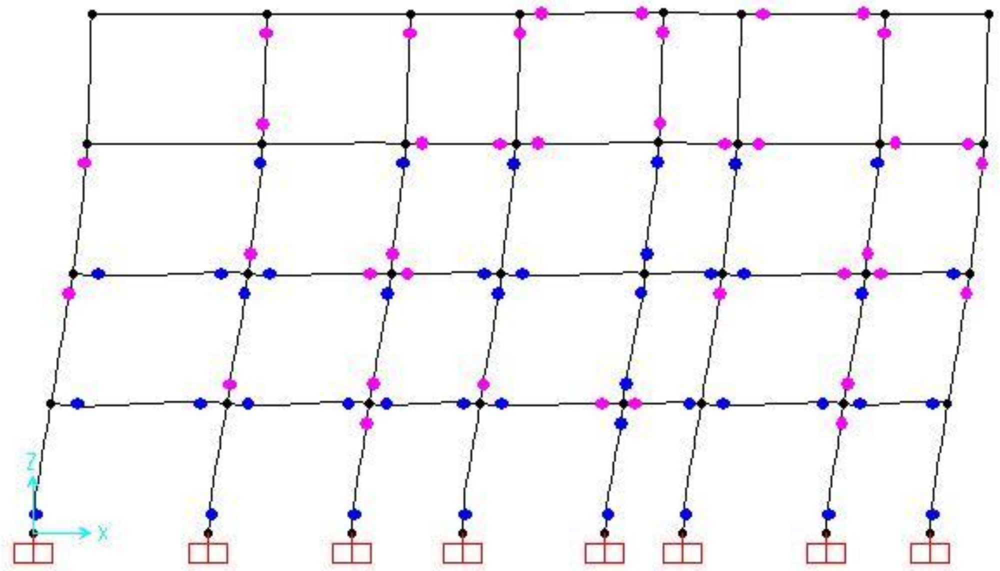


Figure 21 : Formation of hinges at point ‘b’ along section A-A

Figure 22 shows the formation of hinges at point ‘c’ (1.59%) along section A-A

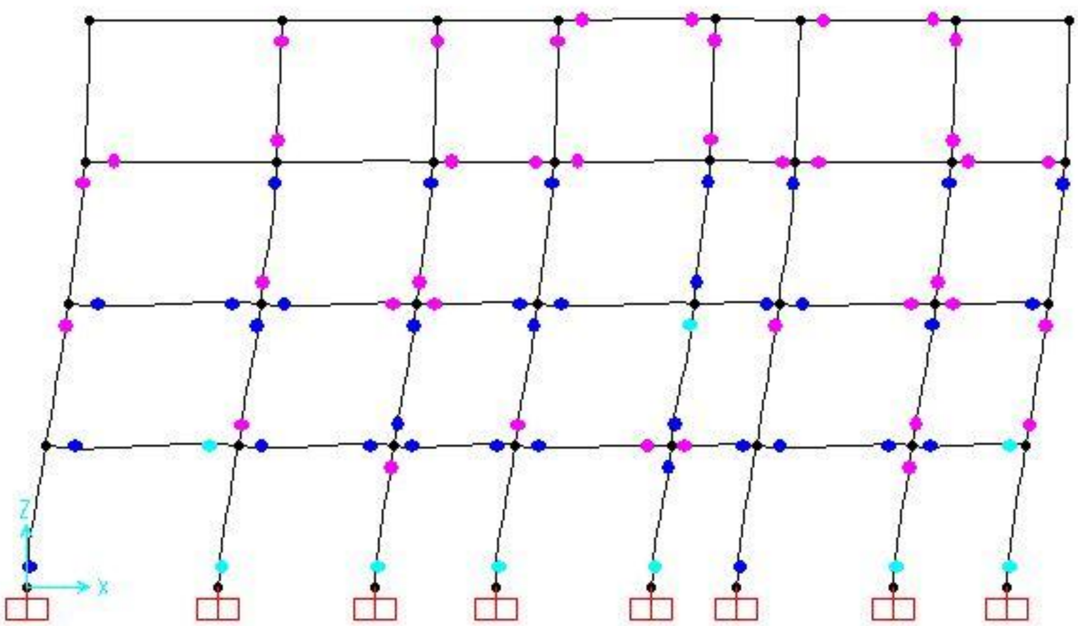


Figure 22: Formation of hinges ‘c’ along section A-A

Pushover Curve along – Y direction

Figure 23 shows the Pushover Curve along the Y direction.

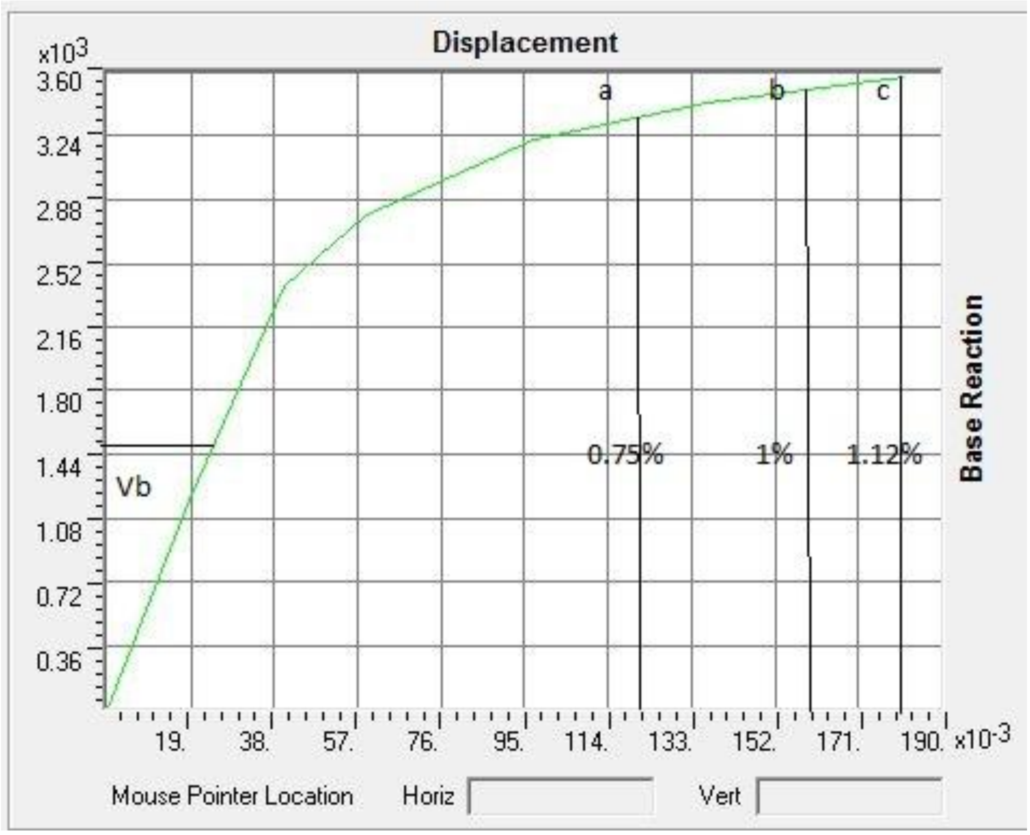


Figure 23: Pushover Curve along Y direction

The unit for Base Reaction is Kn and Displacement is metre. The maximum node displacement is equal to 0.180 m which is 1.12% H. The Pushover Curve shows that the building has fairly high Base Shear Capacity than the Design Base Shear. Points 'a' , 'b' , 'c' are marked on the curve corresponding to 0.75% , 1% and 1.12 % of Displacement respectively. The Base Shear Capacity of the building is approximately 10.2% of the seismic weight of the Building.

Figure 24 shows the formation of hinges in a typical frame of building at point ‘a’ (.75%) displacement.

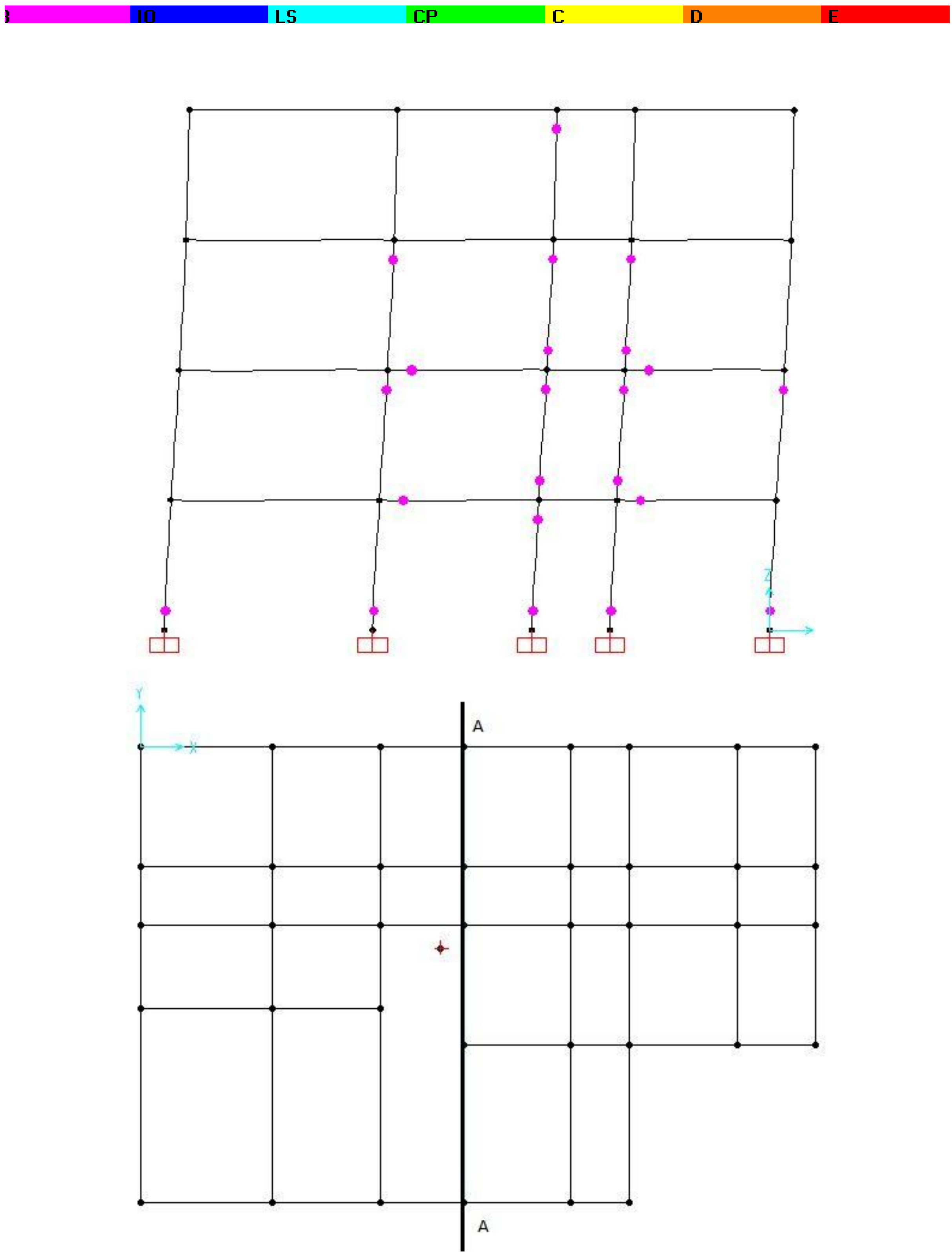


Figure 24: Formation of Hinges in typical frame at point ‘a’ and along section A-A

Figure 25 shows the formation of hinges at point ‘b’ (1%) along section A-A.

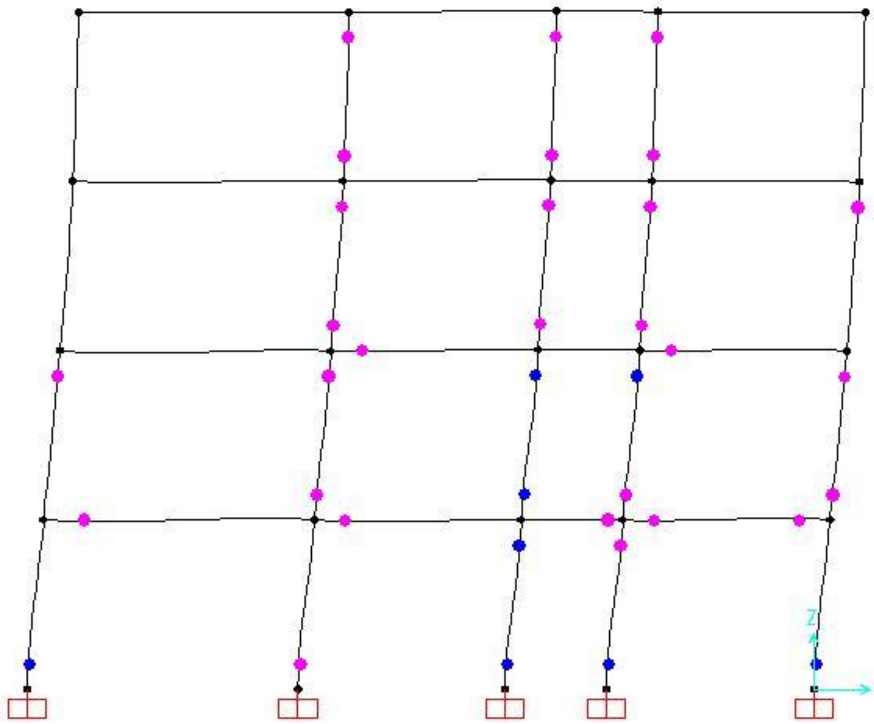


Figure 25: Formation of hinges at point ‘b’ along section A-A

Figure 26 shows the formation of hinges at point ‘c’ (1.12%) along section A-A

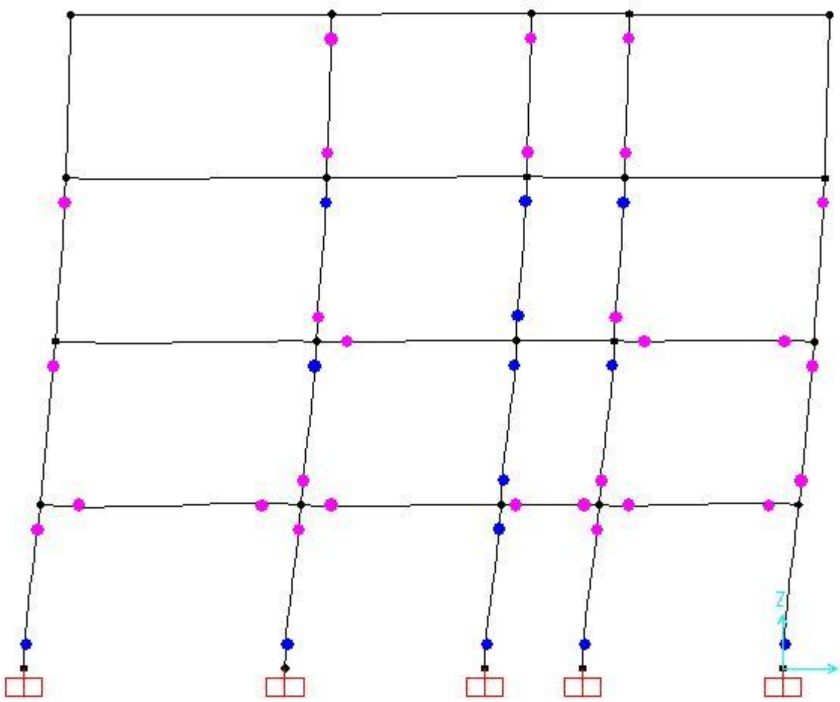


Figure 26: Formation of hinges at point ‘c’ along section A-A

Capacity Spectrum, Demand Spectrum and Peformance Point

Instead of plotting Base Shear with versus Roof displacement, the Base acceleration was plotted with respect to Roof displacement which is known as capacity spectrum. The spectral acceleration and spectral displacement, as calculated from the linear elastic response spectrum for a certain damping (initial value 5%), is plotted in the Acceleration Displacement Response Spectrum (ADRS) format. With increasing non-linear deformation of the components, the equivalent damping and the natural period increase. The spectral acceleration and displacement values can be modified from the 5% damping curve by multiplying a factor corresponding to the effective damping (Table 3, IS 1893: 2002). Thus, the instantaneous spectral acceleration and displacement point (demand point) shifts to a different response spectrum for higher damping. The locus of the demand points in the ADRS plot is referred to as the demand spectrum. The demand spectrum corresponds to the inelastic deformation of the building.

The 'performance point' is the point where the capacity curve crosses the demand curves. If the performance point exists and the damage state at this point is acceptable, the structure satisfies the target performance level.

<u>Pushover Analysis along X direction under DBE</u>

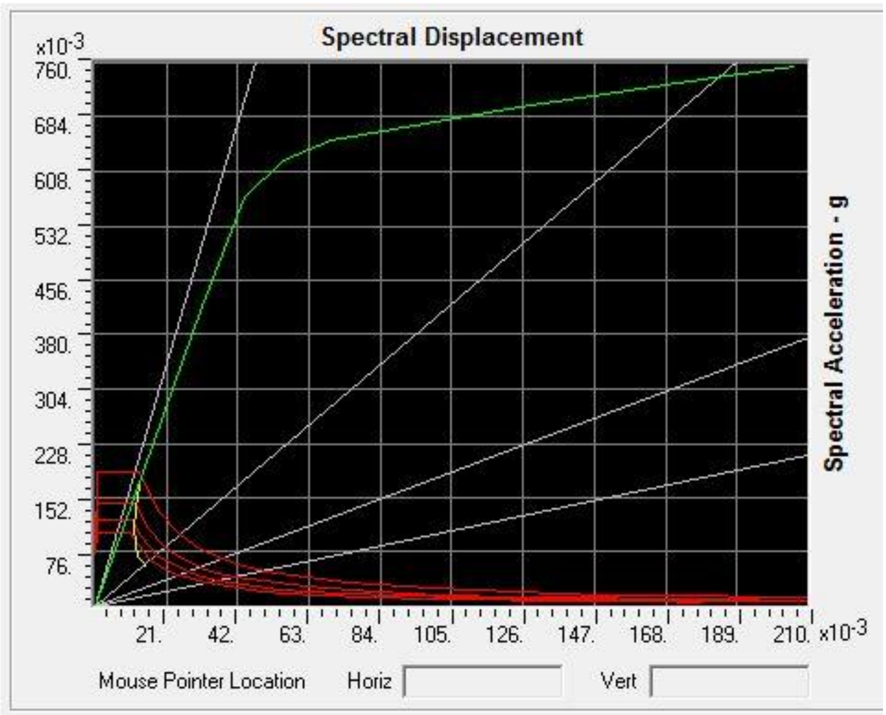


Figure 27: Capacity Spectrum for Pushover along X direction under DBE

Pushover Analysis along Y direction under DBE

Figure 28: Capacity Spectrum for Pushover along Y direction

The Performance point in X & Y direction is given in Table 6 & Table 7 respectively.

Table 6: Status of performance point Push- X(DBE)

Quantity	Value	Quantity	Value
Base Shear (kN)	980	Roof displacement (m)	0.018
Spectral acceleration, S_a (m/s^s)	0.182	Spectral displacement, S_d (m)	0.014
Effective time period, T_{eff} (s)	0.548	Effective damping, β_{eff}	0.050

Table 7: Status of performance point Push- Y(DBE)

Quantity	Value	Quantity	Value
Base Shear (kN)	889	Roof displacement (m)	0.014
Spectral acceleration, S_a (m/s^s)	0.173	Spectral displacement, S_d (m)	0.014
Effective time period, T_{eff} (s)	0.579	Effective damping, β_{eff}	0.050

Pushover Analysis along X Direction under MCE

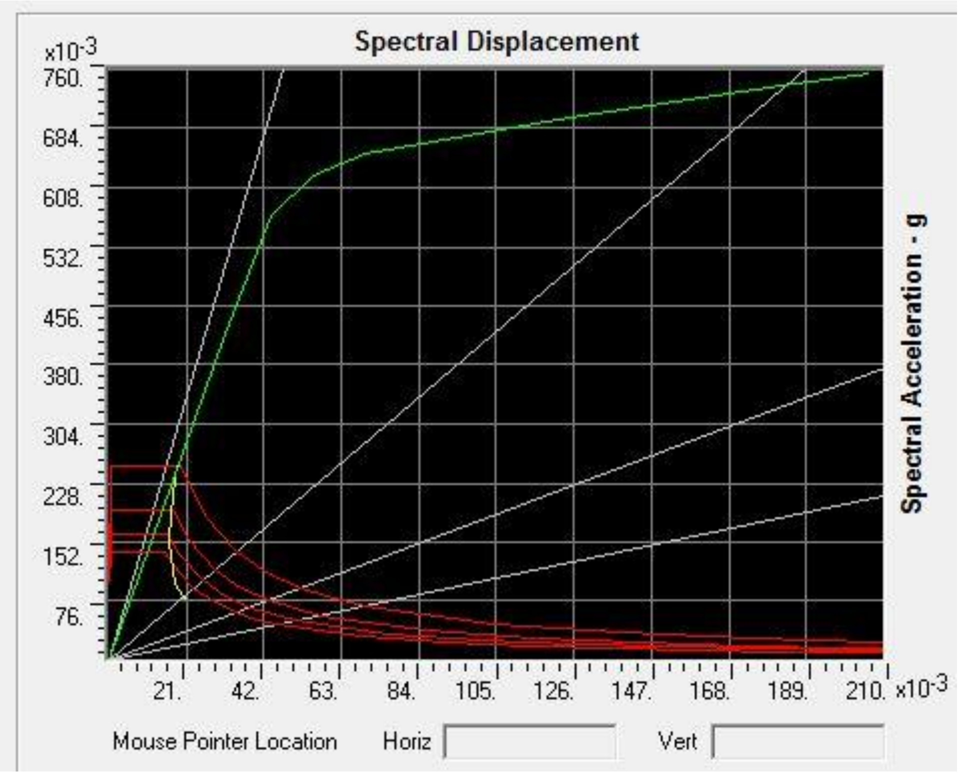


Figure 29: Capacity Spectrum along X direction (MCE)

Pushover Analysis along Y Direction under MCE

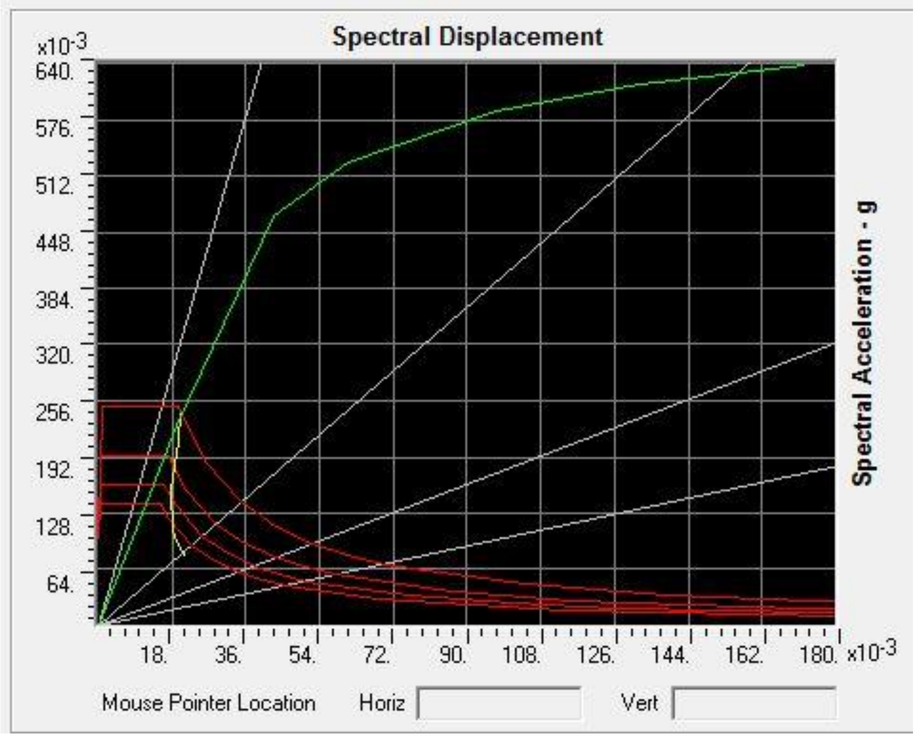


Figure 30: Capacity Spectrum along Y direction (MCE)

The Performance point in X & Y direction is given in Table 8 & Table 9 respectively.

Table 8: Status of performance point Push- X(MCE)

Quantity	Value	Quantity	Value
Base Shear (kN)	1344	Roof displacement (m)	0.024
Spectral acceleration, S_a (m/s^s)	0.250	Spectral displacement, S_d (m)	0.019
Effective time period, T_{eff} (s)	0.548	Effective damping, β_{eff}	0.050

Table 8: Status of performance point Push- Y(MCE)

Quantity	Value	Quantity	Value
Base Shear (kN)	1231	Roof displacement (m)	0.020
Spectral acceleration, S_a (m/s^s)	0.239	Spectral displacement, S_d (m)	0.020
Effective time period, T_{eff} (s)	0.581	Effective damping, β_{eff}	0.051

The roof displacement at which the building is performing corresponds to a base shear or lateral force (Pushover Curve) which is well within elastic limits and no yielding has taken place in any Hinge.

3.5 DISCUSSION & SUMMARY

The Chapter started with a introduction about performance based evaluation and it's importance and then describing the whole Pushover Analysis procedure which a key way to find the Performance Level of a Building.

The Result section contains all the results and graphs for the designed building which includes Pushover Curve , State of different nodes at different push level and capacity Spectrum, Demand Spectrum & Performance point.

<u>Discussion</u>

After studying all the curves and tables in the result section I came to the following conclusion that the Pushover Analysis result show that the Building was able to achieve the performance point along both X and Y direction within the elastic limit range in case of both

Designed Based Earthquake and Maximum Considered Earthquake. The Building was found to fail in the last push due to the failure of columns in the ground floor in the 0-4 m range.

Typical values of roof drifts for the three performance levels are as follows (FEMA 356).

i) Immediate Occupancy: Transient drift is about 1% with negligible permanent drift.
ii) Life Safety: Transient drift is about 2% with 1% permanent drift.
iii) Collapse Prevention: 4% inelastic drift, transient or permanent.

In this case the performance point has maximum displacement of 0.024 m which is less then 1%H , hence the Building is well within elastic limits and comes under operational performance level criteria.

4. SUMMARY & CONCLUSION

4.1 Summary

In the present study an Office building is designed as per indian standard i.e. IS 456:2000 and IS 1893:2002 using an industrially trusted Software STAAD.Pro . The main objective of this Project was to check the kind of performance a building can give when designed as per Indian Standards . After the designing of the proposed Office Building in STAAD.Pro litearture review was carried about the concepts of Performance Based Design Approach which is quite famous in western countries where a Owner can choose the kind of performance he needs/wants from his building. It also helps the Government in setting up laws which makes it compulsory for imporatant public buildings to follow a particulat desired Performance Level. In our Study after designing was completed in STAAD the whole file was imported to SAP 2000 (V14) another trusted industry Software. In SAP the defining and modeling part was carried out which was followed by Pushover Analysis , Collection and presentation of results and last but not the least Analysis of the result.

4.2 Conclusion

Following are the important conclusion made from the following study

- Building designed with IS 1893:2002 found to have a performance as follows:
    1. Operational under MCE
    2. Elastic under DBE

- Pushover Analysis is an elegant tool to visualize the performance level of a building under a given earthquake

- The results in this study show that Indian Standard is very conservative in it's approach.

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b) **Prasad, A.M.; Menon, D; Sarkar, P. and Davis, R.** "Pushover Analysis of Delhi Secretariat Building", Indian Institute of Technology Madras Report No. IC0506CIE119PWDXDEVD. May 2006.

c) **Anirban Sengupta & Bikash Kumar Pati** (2011) Development Of The Non Linear Model For RC Beams By, B.Tech. Project, Department of Civil Engineering , NIT Rourkela.

d) **IIT Madras – SERC Report** (2005) Manual for Seismic Evaluation and Retrofit of Multi-storeyed RC Buildings, A Report published by Indian Institute of Technology Madras and Structural Engineering Research Centre Chennai, March 2005, Funded by Department of Science and Technology (Govt. of India).

e) **Adrian M. Chandler , Nelson T.K. Lam** (2001) Performance Based Design in Earthquake Engineering: a multi disciplinary review, Engineering Structures, Vol. 23, pp 1525–1543

f) **Farzad Naeim, Hussain Bhatia and Roy M. Lobo** Performance Based Seismic Engineering, The Seismic Design Handbook (2nd Edition) California

g) **Trevor E Kelly** Nonlinear Pushover and Time history Analysis, S.E Holmes Consulting Group LTD.

h) **____IS 456:2000** Code of Practice for Plain and Reinforced Concrete, Bureau of Indian Standards. New Delhi.

i) **____IS 1893:2002** Code of Practice for Plain and Reinforced Concrete. Bureau of Indian Standards. New Delhi.

APPENDIX A

STAAD.Pro INPUT FILE

STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 30-nov-2011
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
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9 0 0 18.6; 10 9.8 0 18.6; 11 5.4 0 4.9; 12 9.8 0 4.9; 13 13.2 0 4.9;
14 17.6 0 0; 15 17.6 0 4.9; 16 20 0 0; 17 20 0 4.9; 18 24.4 0 0; 19 24.4 0 4.9;
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ISOTROPIC CONCRETE
E 2.17185e+007
POISSON 0.17
DENSITY 25
ALPHA 1e-005
DAMP 0.05
END DEFINE MATERIAL
MEMBER PROPERTY INDIAN
1 TO 400 PRIS YD 0.4 ZD 0.4
CONSTANTS
MATERIAL CONCRETE ALL
SUPPORTS
1 TO 3 5 TO 30 32 TO 40 FIXED
DEFINE 1893 LOAD
ZONE 0.075 RF 1 I 1 SS 1 DM 0.05
SELFWEIGHT 1
MEMBER WEIGHT
39 TO 100 139 TO 200 239 TO 300 UNI 20
FLOOR WEIGHT
YRANGE 3.8 16.2 FLOAD 3.75
YRANGE 3.8 12.2 FLOAD 0.75
LOAD 1 LOADTYPE Seismic  TITLE SL IN X
1893 LOAD X
LOAD 2 LOADTYPE Seismic  TITLE SL IN Z
1893 LOAD Z
LOAD 3 LOADTYPE Dead  TITLE DL
SELFWEIGHT Y -1
MEMBER LOAD
39 TO 100 139 TO 200 239 TO 300 UNI GY -20
FLOOR LOAD
YRANGE 3.8 16.2 FLOAD -3.75 GY
LOAD 4 LOADTYPE Live  TITLE LL
FLOOR LOAD
YRANGE 3.8 16.2 FLOAD -3 GY
LOAD COMB 5 COMBINATION LOAD CASE 5
3 1.5 4 1.5
LOAD COMB 6 COMBINATION LOAD CASE 6
1 1.2 3 1.2 4 1.2
LOAD COMB 7 COMBINATION LOAD CASE 7
1 -1.2 3 1.2 4 1.2
LOAD COMB 8 COMBINATION LOAD CASE 8
1 1.5 3 1.5
LOAD COMB 9 COMBINATION LOAD CASE 9
1 -1.5 3 1.5
LOAD COMB 10 COMBINATION LOAD CASE 10
1 1.5 3 0.9
LOAD COMB 11 COMBINATION LOAD CASE 11
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LOAD COMB 12 COMBINATION LOAD CASE 12
2 1.2 3 1.2 4 1.2
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LOAD COMB 13 COMBINATION LOAD CASE 13
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2 1.5 3 1.5
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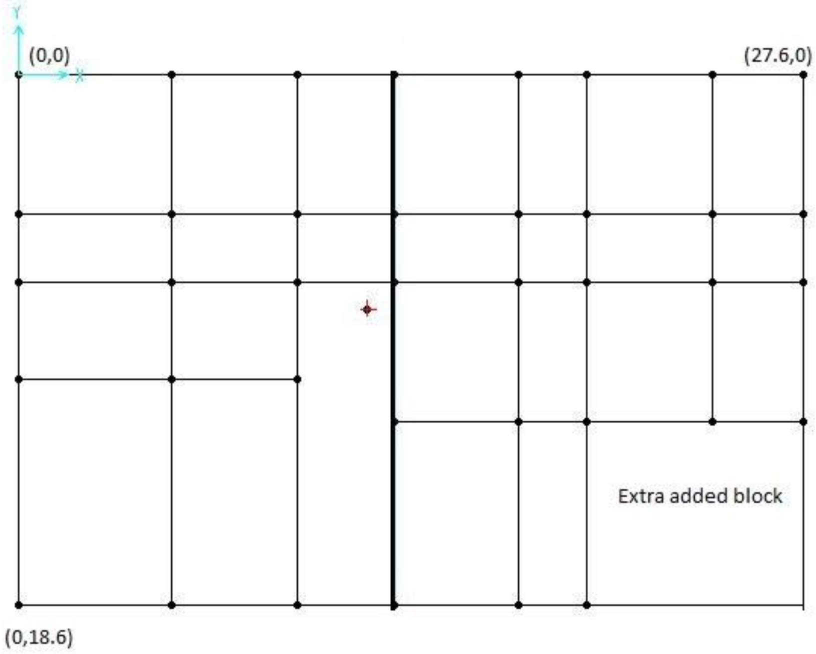
2 -1.5 3 1.5
LOAD COMB 16 COMBINATION LOAD CASE 16
2 1.5 3 0.9
LOAD COMB 17 COMBINATION LOAD CASE 17
2 -1.5 3 0.9
PERFORM ANALYSIS PRINT ALL
START CONCRETE DESIGN
CODE INDIAN
UNIT MMS NEWTON
FC 20 ALL
FYMAIN 415 ALL
FYSEC 415 ALL
MAXMAIN 25 ALL
MAXSEC 12 ALL
MINMAIN 12 ALL
MINSEC 8 ALL
UNIT METER KN
DESIGN BEAM 39 TO 100 139 TO 200 239 TO 300 339 TO 400
DESIGN COLUMN 1 TO 38 101 TO 138 201 TO 238 301 TO 338
END CONCRETE DESIGN
FINISH

APPENDIX B

CALCULATION OF FLOOR MASS CENTRE

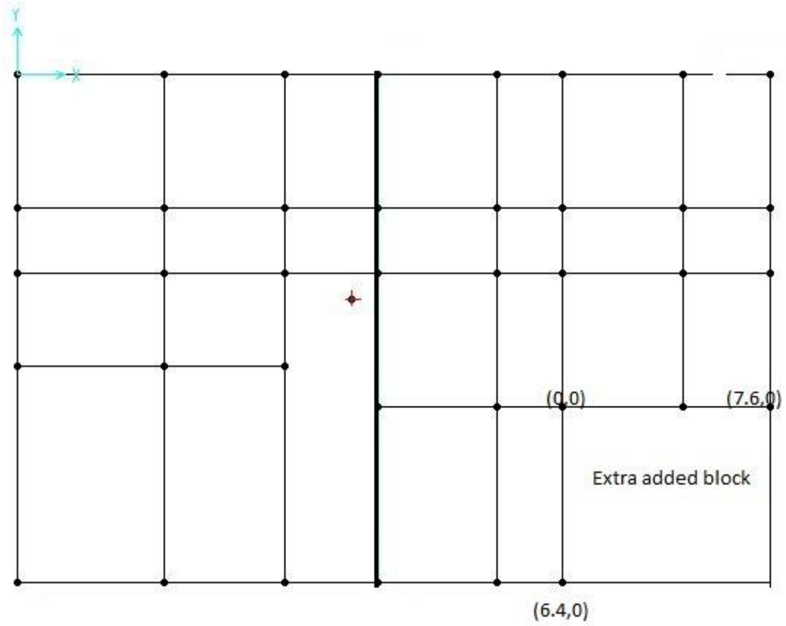
The idea of Calculating Floor Mass Centre is first to select the floor and find it's FMC. As all the floors are symmetric and similar there FMC will lie in a straight a line.

Inorder to calculate the Centre first of all we have to add an extra block to make the floor regular and find it's centre .



The Centre of Mass of this Symmetric Floor floor is equal to (27.6/2 , 18.6/2) = (13.8 , 9.3),

Next the centre of mass of the added block is found



The Centre of mass of added block is found to be (3.8 , 3.2) with respect to the new reference point (0,0).

In order to calculate the FMC of the designed building

X= (513.36x13.8 – 48.64x3.8)/(513.36+48.64) = 12.277

Y= (513.36x9.3 – 48.64x3.2)/(513.26+48.64) = 8.218

The Floor Mass Centre is (12.277, 8.218).